91343R01
VOL. I
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PROGRAM MANAGER
RMA CONTAMINATION CLEANUP

U.S. ARMY
MATERIEL COMMAND

— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

COMPREHENSIVE MONITORING PROGRAM

Contract Number DAAA15-87-0095

FINAL SURFACE WATER DATA ASSESSMENT REPORT FOR 1989

JUNE 1990

Version 2.0

Volume I

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
06/00/90

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
COMPREHENSIVE MONITORING PROGRAM, FINAL SURFACE WATER DATA ASSESSMENT REPORT FOR 1989, VERSION 2.0

5. FUNDING NUMBERS
DAAA15 87 0095

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
ROBERT L. STOLLAR AND ASSOCIATES
DENVER, CO

8. PERFORMING ORGANIZATION REPORT NUMBER
91343R01

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
HARDING LAWSON ASSOCIATES
DENVER, CO

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

THE 1989 SURFACE WATER REPORT IS DIVIDED INTO SIX SECTIONS AND TWO APPENDICES. SECTION 1 PROVIDES A GENERAL HISTORICAL REVIEW OF THE DEVELOPMENT OF THE RMA. THE HISTORICAL ROLE OF SURFACE WATER FEATURES AT RMA, THE EFFECTS OF RMA INDUSTRIAL ACTIVITIES ON SURFACE SYSTEM MORPHOLOGY, AND THE MAJOR DRAINAGE BASINS THAT EXIST ON RMA ARE PRESENTED IN SECTION 2. SECTION 3 PROVIDE A DETAILED DISCUSSION OF THE PRESENT CMP PROGRAMS STRATEGIES AND METHODOLOGIES. SECTION 4 PRESENTS THE WATER QUALITY AND QUANTITY DATA COLLECTED DURING FISCAL YEAR 1989. SECTION 5 INTERPRETS THE COLLECTED SURFACE WATER DATA. SECTION 6 PROVIDES CONCLUSIONS AND A DETAILED SUMMARY OF FY89 RESULTS.
APPENDIX A INCLUDES INFORMATION RELATED TO SURFACE WATER QUANTITY AND APPENDIX B INCLUDES INFORMATION RELATED TO SURFACE WATER QUALITY.

14. SUBJECT TERMS
CONTAMINANTS, SAMPLING, DRAINAGE BASINS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

[redacted]

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EXECUTIVE SUMMARY

The Comprehensive Monitoring Program (CMP) at the Rocky Mountain Arsenal (RMA) is designed to provide both continual and long-term monitoring of ground water, surface water, air, and biota. This report covers the surface-water monitoring program for Fiscal Year 1989 (FY89), along with a review of surface-water data (quantity and quality) accumulated prior to FY89.

The present CMP for surface water has evolved from a series of programs and studies beginning in 1975 with the "360° Monitoring Program". Several groups and agencies have been involved. Installation of gaging stations began in the early 1980's. Stream flow records for some stations that began in 1983 and over 18,000 water quality records for the period 1979 to 1988 were reviewed and compared to FY89 data.

Prior to the CMP the most common organic compounds, listed in order of number of sites detected, were:

- dibromochloropropane (DBCP) -- 10 sites
- diisopropylmethyl phosphate (DIMP) -- 7 sites
- aldrin (ALDRN) -- 7 sites
- dicyclopentadiene (DCPD) -- 6 sites
- chloroform (CHCL3) -- 6 sites

Some organic contaminants were detected in surface water entering RMA, including 1,1,1-trichloroethane (111TCE) and benzothiazole (BTZ).

During Fiscal Year 1988 (FY88) 29 surface-water quality locations were sampled and analyzed for 39 organic compounds. During the spring the site with most organic compound detections was SW36001 (Basin A monitoring station) with 16 detections followed by SW01002 (South Plants water tower pond) with 11 detections. The most common organic compounds that were detected during FY88 are listed below in order of number of sites detected:

- dieldrin (DLDRN) -- 5 sites
- chloroform (CHCL3) -- 4 sites
- aromatic volatile compounds (BETX) -- 4 sites
- hexachlorocyclopentadiene (CL6CP) -- 4 sites
- dicyclopentadiene (DCPD) -- 3 sites

During FY88 the most inorganic detections, listed in order of number of sites detected, were:

- zinc (total) -- 33 sites
- mercury (total) -- 31 sites
- lead (total) -- 31 sites
- arsenic (total) -- 29 sites

During FY89 organic compounds were detected at 21 sites out of 30 sites that were sampled. The site with the most organic compound detections during the spring was SW36001 (Basin A) with 37 different organic compound detections followed by SW01002 (South Plants water tower pond) with 20 detections. The most common organic compounds, listed in order of number of sites detected, were:

- Vapona -- 7 sites
- dimethylmethylphosphonate (DMMP) -- 6 sites
- endrin -- 6 sites
- dieldrin -- 5 sites
- hexachlorocyclopentadiene (CL6CP) -- 5 sites
- p,p'-DDE (PPDDT) -- 5 sites
- aldrin, DIMP, chlordane, isodrin -- 4 sites

During FY89 the most common inorganic detections, listed in order of number of sites detected, were:

- zinc (total) -- 10 sites
- arsenic (total) -- 10 sites
- mercury (total) -- 4 sites

During FY88 sediment quantity analysis at RMA was studied at three sites. During FY89 sediment quantity analyses were performed at nine sites. During FY89 sediment quantity samples were obtained during baseflow and high event conditions. The results that were obtained during FY89 indicate over 10 times the amount of total suspended sediments are being deposited in the streams during a high event than during baseflow conditions.

During FY88 sediment quality analysis of stream bottom sediments was performed on samples from 10 locations and during FY89 sediment quality analysis was performed on samples from 18 locations. During FY89 organic compounds were detected at 16 sites. During the spring the site with the most organic detections in sediments was SW36001 with nine organic compounds detected followed by SW01002 with six detections. The most common organic detections in sediments, listed in order of number of sites detected, were:

- atrazine -- 15 sites
- dieldrin -- 6 sites
- CPMSO -- 6 sites
- endrin, isodrin, aldrin -- 5 sites

During FY89 seven high (storm) event samples were collected at surface-water sampling locations along the southern boundary and at interior locations that normally do not display surface water. Organic compounds were detected at SW11001 (Peoria Interceptor), SW08003 (South First Creek) and SW04001 (Motor Pool). At SW11001 2,4,5 trichlorophenol, parathion and xylene (o,p) were detected in the sample. In the sample obtained from SW08003, DBCP was detected. At SW04001 dieldrin was detected in the sample. Inorganic compounds were detected at SW12005 (South Uvalda), SW11001 and SW11002 (Havana Interceptor). Zinc was detected in samples collected during storms at SW12005, SW11001 and SW11002. Copper was also detected at SW11002 in the sample collected during a storm.

During FY89 surface-water quantity monitoring was conducted at 17 stations located in three of five drainage basins defined on RMA. Stream stage data were recorded continuously at 11 stations and lake or pond levels were obtained weekly from five stations. New controls were constructed and continuous recording equipment were installed along First Creek at South First Creek, North First Creek and First Creek Off-Post locations.

Surface-water inflow to RMA and Irondale Gulch drainage basin was measured at four stations: Highline Lateral (SW12007), South Uvalda (SW12005), Peoria Interceptor (SW11001) and Havana Interceptor (SW11002). All these stations monitor surface-water runoff originating from areas south of RMA, except Highline Lateral which monitors irrigation water diverted from the South Platte River. The South Uvalda, Peoria Interceptor, and Havana Interceptor stations measure incoming surface-water from developed commercial, industrial and residential areas. In addition, stream flows and lake levels within Irondale Gulch drainage basin are measured at eight stations. Flow stations were North Uvalda (SW01001), Ladora Weir (SW02001) and South Plants Ditch (SW01003). These stations monitor surface-water flow to and from the South Plants Lakes. Water levels were

measured at Upper Derby Lake (SW01004), Lower Derby Lake (SW01005), Ladora Lake (SW02003), Lake Mary (SW02004) and Havana Pond (SW11003).

Surface-water flow within the First Creek drainage basin along First Creek is monitored at three locations. South First Creek monitoring station (SW08003) measures inflow from southeast off-post sources, North First Creek monitoring station (SW24002) measures stream flow leaving RMA and First Creek Off-Post monitoring station (SW37001) measures flow between the northern RMA boundary and Highway 2.

Surface-water was measured in the South Platte drainage basin at Basin A monitoring station (SW36001). This station is used to monitor runoff originating from South Plants area.

New stream stage data acquisition systems were installed during FY89 at the South First Creek, North First Creek, South Uvalda and Havana Interceptor monitoring stations. This equipment consisted of a digital data logger and a nitrogen bubbler system. The system was installed in order to collect stage data during the freezing months and to ease data reduction efforts. At all other stream monitoring stations datapod digital recorders were also installed in order to ease data reduction efforts.

Surface-water quantity analyses included evaluation of stream flow characteristics and extremes, as well as calculation of mean monthly, maximum daily and minimum daily flows. Stream flow hydrographs were analyzed to describe flow conditions in response to six storms that occurred during FY89. In addition, stage data collected at one continuous monitoring station (South Uvalda) from October 1985 to September 1987 were analyzed for completeness and accuracy and was compared to present stage data collection procedures. Some differences in the data were noted and were attributed to techniques used in data acquisition and analysis.

This report also contains information on ground-water and surface-water interaction in the South Plants Lakes area and along First Creek. This study involved the hydrographic and chemical analysis of surface-water locations and ground-water wells located in these areas. The data indicted significant interaction in the South Plants Lakes area and along First Creek.

1.0 INTRODUCTION

The Comprehensive Monitoring Program (CMP) is designed to provide both continual and long-term monitoring of ground water, surface water, air, and biota. Each environmental medium is being monitored within a separate program element. Each element has detailed objectives, outlined in respective technical plans, which establish monitoring guidelines, analytical parameters, and sampling protocol and strategies.

This Fiscal Year 1989 (FY89) Surface-Water Report is divided into six sections and two appendices. FY89 is defined as the period from October 1, 1988 to September 30, 1989. The use of Water Year 1989 in this report also corresponds to the same time period as FY89 (October 1, 1988 to September 30, 1989). Section 1 provides a general historical review of the development of the Rocky Mountain Arsenal (RMA) surface-water program. The historical role of surface-water features at RMA as well as their general characteristics and interrelationships are presented in Section 2. The effects of RMA industrial activities on surface-water system morphology are also presented in this section. Section 2 also presents the major drainage basins that exist on RMA. Section 3 provides a detailed discussion of the present CMP program's strategies and methodologies. The relative positioning of the surface-water quantity monitoring stations and the surface-water quality sampling locations relative to major RMA drainage basins are also discussed in the section. Section 4 presents the water-quality and quantity data collected during Fiscal Year 1989 in the major RMA drainage basins. An associated assessment of the procedures used while collecting and reviewing the data is also included in this section. Section 5 interprets the collected surface-water data. Water-quality issues addressed include a comparison of current program results to Fiscal Year 1988 (FY88) results, the possible sources of detected target analytes, and an analysis of the adequacy of the present analyte list. Section 6 provides conclusions and a detailed summary of FY89 results. Relationships noted between water quality and corresponding stage or discharge are also reviewed in this section. Appendix A includes information related to surface-water quantity and Appendix B includes information related to surface-water quality.

1.1 Site Background

The RMA occupies approximately 27 square miles (sq mi) in south Adams County, Colorado and is located about 6 miles (mi) northeast of downtown Denver (Figure 1.1-1). Before RMA was built in 1942, land in the area was used principally for dry farming, some irrigated farming and cattle grazing. At various times from 1942 to 1946, the U.S. Army produced chemical and incendiary weapons for use in World War II. Chemical agents were also produced from 1953 to 1957. Munitions-filling operations continued at RMA until late 1969 (Ebasco Services, Inc., et al., 1989a).

From 1970 to 1982, Army operations at RMA centered on demilitarization of chemical weaponry. Between 1946 and 1982, parts of RMA were leased to private companies involved in chemical manufacturing. The two principal lessees, Julius Hyman and Company and Shell Chemical Company, manufactured a variety of pesticides, insecticides, herbicides and soil fumigants (Ebasco Services, Inc., 1988).

Land use surrounding RMA is variable. Mixed residential housing and light industrial manufacturing facilities are present along its western and southern borders. A part of Stapleton International Airport's (Stapleton Airport) north-south runway system extends into the southwest part of RMA. Land north and east of RMA is used mainly for farming and ranching. Principal features of RMA are shown on Figure 1.1-2.

1.2 Surface-Water Monitoring Program Objectives and Activities

The purpose of the Surface-Water Monitoring Element of the CMP at RMA is to:

- Monitor surface-water quality and surface-water hydrology for the assessment of rates and potentials of contaminant migration in both on-post and off-post areas;
- Maintain a regional surface-water monitoring program to support and verify the Remedial Investigation/Feasibility Study (RI/FS) program;
- Maintain a regional surface-water monitoring program as part of the surface-water management program at RMA; and
- Characterize and monitor quality and quantity of surface water flowing onto RMA from off-post areas.

1.2.1 FY88 Program Activities

The major activities of FY88 included:

- Review of previous RMA surface-water quality data and evaluation of its usefulness in trend analyses when compared to current program results;
- Review and comparison of historical instantaneous discharge data to that obtained during the CMP;

- Review, refinement and extension of rating curves developed by previous contractors at selected monitoring stations;

- Monitor surface-water quantity and quality;

- Monitor sediment quantity and quality;

- Maintenance of the existing monitoring network and a modification analysis of the network; and

- Obtain surface-water/ground-water interaction data.

All surface-water instantaneous flow data collected since April of 1985 were compiled, critically reviewed, and presented in the FY88 report. Procedures used to collect and reduce this information were evaluated. The 1985 to 1987 instantaneous flow data were reviewed to validate historical flow trends and document any changes noted in the natural flow system that may have affected the present monitoring network. Historical surface-water quality data (back to 1979) were also reviewed and were assessed to determine their validity and usefulness as part of a comprehensive database. Surface-water quality data collected from April through October 1988, were compared to that collected during the Tasks 4, 39 and 44 (1985-1987) and the 360° Monitoring Program (1979-1986).

In addition to verifying the results of the Remedial Investigation program, CMP Surface-Water element results expand the available database that could be used for the Surface-Water management program at RMA. The present surface-water program could also be used to monitor the effect of interim response actions on the surface-water system. A verifiable historical database has to be maintained in order to judge the effect of future RMA remedial actions on surface-water flow and quality. This database could be used to monitor off-post upgradient activities such as ranching, farming, and urban or industrial activities that can affect the quality and quantity of surface-water entering RMA from the South.

During the first year of CMP operation, the existing stream flow and quality monitoring network employed by the Remedial Investigation (Task 44) was generally maintained. The R. L. Stollar & Associates, Inc. (Stollar) team collected stage data on a continuous basis for FY88 from April 4, 1988 to September 30, 1988. Data collected from October and November 1987 by Environmental Science and Engineering, Inc. (Hunter/ESE) were also evaluated and included in the FY88 report

in order to present as complete a record as possible of conditions for Water Year 1988 (October 1, 1987 - September 30, 1988). (Note: Water Year corresponds to Fiscal Year.) The use of the Water Year as the chosen monitoring period for the collection and presentation of data is based on the concept of the yearly hydrologic cycle in North America as defined by U.S. Geological Survey. Instantaneous discharge data were collected monthly at active stream monitoring stations and when possible during high flow storm events. Old rating curves needed to be refined or redeveloped to document Water Year 1988 stage-discharge relationships at many of the active monitoring stations. Staff gage readings were taken on the lakes and converted to elevation to monitor storage changes over time and to confirm previously established elevation/volume relationships. Water-level measurements from monitoring wells near surface-water features were used to help assess surface-water and ground-water interactions in the lake areas and in other selected areas. To supplement this assessment, ground-water and surface-water samples taken at locations proximate to each other were compared geochemically to document interchange between the two systems.

A network of sites coordinated with sample locations previously used during the Remedial Investigation program were sampled to determine surface-water quality during FY88. Sampling frequency (seasonal and high event) and analytical parameters varied depending on locations. A preliminary assessment of the role of suspended and bed load sediment transport on contaminant migration was also undertaken during FY88.

1.2.2 FY89 Program Activities

The network established during FY88 was utilized during FY89. The network was expanded by installing new stations in the areas of South First Creek, North First Creek and First Creek Off-Post. The FY89 surface-water program was expanded by the following activities:

- Installation of digital equipment (datapods and data loggers) for stage level measurements;
- Installation of bubbler systems at four stations in order to obtain stage data throughout the freezing months (December to April);
- Modification and refabrication of controls at First Creek Off-Post, North First Creek, South First Creek, Peoria Interceptor and Havana Interceptor stations;
- Utilization of long-throated portable flumes for low flow measurements;

- Expansion of GC/MS analysis to more internal sampling locations;

- Utilization of automated samplers for obtaining water quality samples during high events;

- Acquisition of more water quality samples during high events than during FY88;

- Obtainment of suspended sediment samples for quantative analysis;

- Obtainment of bottom sediment samples for qualitative analysis;

- Acquisition of more well water level measurements for use in ground-water/surface-water interaction study; and

- Obtainment of gain/loss data for use in ground-water/surface-water interaction study.

In addition, the CMP surface-water program during Water Year 1989 collected instantaneous discharge and stage data, lake stage water levels, water-level measurements from surface-water related wells and high event water quality samples. New rating curves were generated for North and South First Creek stations and First Creek Off-Post station and refined for the other stations. Water quality samples were also obtained from the surface-water sampling locations during the spring and fall.

1.3 RMA Surface-Water Investigations

A review of the historical development of the RMA surface-water program was undertaken as part of this report preparation. The review consisted both of documenting previous programs and evaluating the reported data. This section provides an overview and description of historical RMA water-quality and quantity programs. Table 1.3-1 provides a synopsis of these programs. Sections 1.3.1 (Surface-water Quantity Investigations) and 1.3.2 (Surface-water Quality Investigations) provide additional information regarding details of the individual studies and their general results. A comparison of FY88 and FY89 data are presented and evaluated in Section 5.

The present surface-water monitoring program has evolved from a series of programs and studies originating in 1975. The first sampling program implemented at RMA used monitoring wells and surface-water sites both within and around the Arsenal. Sampling was initiated because of

Table 1.3-1 Chronology of RMA Surface-Water Monitoring

Date	Organizations Responsible for Monitoring	Program Name and Activities
January 1976 - November 1976	1	Revision I-360° Program . Surface- and ground-water sampling both on- and off-post
November 1976 - 1982	1	Revision II-360° Program . Surface- and ground-water sampling quarterly, both on- and off-post
1983 - 1985	2	Revision II-360° Program . Surface- and ground-water sampling quarterly, both on- and off-post

1 - Data collected by Tri-County Health Department; Colorado Department of Health; Shell Chemical Company; RMA Personnel

2 - Data collected by Tri-County Health Department; Colorado Department of Health; RMA Personnel

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Table 1.3-1 Chronology of RMA Surface-Water Monitoring (continued)

Date	Organizations Responsible for Monitoring	Program Name and Activities
1981 - 1982	Resource Consultants, Inc.	. Delineate watersheds and major flow paths . Calculate a water balance based on estimated flows
Spring 1982	Resource Consultants, Inc.	. Install gaging stations at South First Creek, South Uvalda Interceptor, Basin A inflow, Ladora Weir, North Uvalda Interceptor (relocated) and South Plants Ditch . 7 gaging stations in place and being monitored for stage and discharge
October 1982 - September 1983	Resource Consultants, Inc.	. Gaging stations installed on Peoria Interceptor, Havana Interceptor and North First Creek . North Uvalda station moved to present location . Staff gage installed at Havana Pond . 10 gaging stations in place and being monitored for stage and discharge
May - December 1984	Jack Dildine (Waterways Experiment Station); Bill Krupke (subcontractor)	. Installation of concrete control structures at South Uvalda, North Uvalda, South First Creek, North First Creek on-post and Peoria Interceptor

SWAR2-89.TBL

Table 1.3-1 Chronology of RMA Surface-Water Monitoring (continued)

Date	Organizations Responsible for Monitoring	Program Name and Activities
December 1985 - April 1986	Hunter/ESE	Revision III-360° Program . Surface- and ground-water sampling off-post1985Hunter/ESE; Resource Consultants, Inc. (subcontractor) Task 4 - Water Quantity/Quality Survey Program . Monitoring at 10 gaging stations for stage and discharge . 30 sites designated for sampling . Installation of 2 rain gages on RMA
September 1985 - February 1986	Hunter/ESE; Resource Consultants, Inc. (subcontractor)	Task 4 - Initial Screening Program . Repair and rehabilitation of existing recording stations . Install staff gage on Lake Mary .. Monitor water-surface elevations weekly on Upper and Lower Derby, Ladora Lake and Lake Mary . Monitor 11 gaging stations for stage and discharge . 16 on-post surface-water sites sampled

Table 1.3-1 Chronology of RMA Surface-Water Monitoring (continued)

Date	Organizations Responsible for Monitoring	Program Name and Activities
December 1985 - January 1986	Hunter/ESE; Resource Consultants, Inc. (subcontractor)	Task 4 - Final Screening Program . Addition of a recording station off-post on North First Creek . 12 recording stations in place and monitored for stage and discharge . Monitor surface-water elevations on Upper and Lower Derby, Ladora Lake and Lake Mary on a weekly basis . 46 on-post sites designated for quarterly sampling . 19 on-post and 11 off-post surface-water sites sampled during 3rd Quarter FY86 . 21 on-post and 9 off-post surface-water sites sampled during 4th Quarter FY86
December 1986 - September 1987	Hunter/ESE	Task 39 - Off-Post Remedial Investigation/Feasibility Study . 11 off-post surface-water sites designated for sampling

Table 1.3-1 Chronology of RMA Surface-Water Monitoring (continued)

Date	Organizations Responsible for Monitoring	Program Name and Activities
March 1987 - November 1987	Hunter/ESE Resource Consultants, Inc. (Subcontractor)	Task 44 . 12 recording stations in place and monitored for stage and discharge . Monitor water surface elevations on Upper and Lower Derby, Ladora Lake and Lake Mary . 40 sites designated for quarterly sampling on- and off-post
April 1988 - September 1988	R.L. Stollar & Associates, Inc. Harding Lawson Associates (subcontractor) Riverside Technology, Inc. (subcontractor)	Comprehensive Monitoring Program (FY88) . Monitor existing 10 recording stations for stage and discharge (North First Creek station destroyed July 1987, First Creek Off-post station inoperative due to non-functioning control structure) . Monitor water surface elevations on Upper and Lower Derby, Ladora Lake, and Lake Mary . Monitor totalizing flow meter at Sewage Treatment Plant effluent discharge location . 35 sites designated for sampling on- and off-post

Table 1.3-1 Chronology of RMA Surface-Water Monitoring (continued)

Date	Organizations Responsible for Monitoring	Program Name and Activities
October 1988 - September 1989	R.L. Stollar & Associates, Inc. Harding Lawson Associates (subcontractor) Riverside Technology, Inc. (Subcontractor)	Comprehensive Monitoring Program (FY89) . Continued FY88 Program . Added new monitoring stations and controls at South First Creek, North First Creek, and First Creek Off-Post

organic solvents and phthalate esters detected in RMA wells by the Colorado Department of Health. It was believed that sources outside RMA might be contributing to the contamination. This was called the Revision I-360° Monitoring Program (U.S. Army, 1977). Program participants included the U.S. Army, Shell Chemical Company and the Colorado Department of Health. The 360° Monitoring Program was initiated in January 1976 and included a combined total of 124 ground-water monitoring wells and surface-water sites on or adjacent to RMA. Additionally, 5 off-post surface-water sites and 24 private wells were selected by the Tri-county District Health Department (Hunter/ESE, 1986a). In November 1976 the program was revised, resulting in analyses being conducted quarterly for 12 surface-water locations on RMA and 10 off-post sites. Under this new program, identified as the Revision II-360° Program, the network of off-post surface-water sites established in the original Revision I-360° Program remained essentially the same (U.S. Army, 1977). With the closing of Shell Chemical Company's facilities at RMA in 1982, Shell's participation in the program was reduced (Ward, 1984). The Revision III-360° Program, implemented in 1985, consisted of 11 off-post surface-water sampling sites (Hunter/ESE, 1986a).

The first comprehensive monitoring effort directed at understanding surface-water flow conditions at RMA began in 1982 by an Army contractor, Resource Consultants, Inc. (RCI). They were responsible for installing the gaging equipment used at most stations being operated at the Arsenal today. During the period from 1982 to 1984, 10 monitoring stations were constructed as shown in Table 1.3-1, although flow control structures had been previously established. Stage and discharge data were collected and rating curves were developed. Flow measurements were obtained at gaging stations with natural channel sections. Flow measurements were not obtained at Highline Lateral and Basin A inflow, where rated structures existed. From 1982 to 1984, while RCI was conducting the surface-water gaging program, surface-water chemical sampling was being carried out concurrently under the Revision II - 360° monitoring program. In 1984 an independent contractor (Bill Krupke), installed concrete control structures at 5 of the monitoring stations under the direction of U.S. Army Waterways Experimental Station. He also collected stage and discharge data throughout the entire network.

Task 4 was initiated in 1985 to provide a coordinated surface-water quality and quantity monitoring program. A main objective of Task 4 was to develop a quality core database and use in Remedial Investigation/Feasibility Study analysis (Hunter/ESE, 1988a). Hunter/ESE managed the program, with RCI providing substantial support in collecting and interpreting surface-water flow and lake level information. The goals of the surface-water portion of the Task 4 water quality and quantity survey were twofold. Separate efforts were established to determine a surface-water mass balance for RMA and water quality at 30 designated on-post sites (Hunter/ESE, 1986a). The first phase of Task 4 was conducted under the Initial Screening Program (ISP) from September 1985 through

February 1986. Initial efforts pertaining to the surface-water portion of the program were directed at repair and rehabilitation of existing monitoring devices and recording stations. Sixteen on-post surface-water sites were sampled (Hunter/ESE, 1987).

Surface-water quantity and quality data continued to be gathered during the third and fourth quarters (spring and summer) of FY86 under Task 4. These results were reported in the Final Screening Program report (Hunter/ESE, 1988a). The Final Screening Program was essentially the same as that developed for the Initial Screening Program. A core database was maintained as a baseline for future studies which included data on surface-water conditions, ground-water recharge, changes in contaminant migration, and the effects of expanding urbanization (Hunter/ESE, 1988a). The surface-water quantity monitoring network used during the Initial Screening Program was expanded by the addition of a station off-post on First Creek near Highway 2. There were 46 potential on-post surface-water sampling sites and 11 potential off-post sites incorporated into the surface-water quality monitoring network (Table 1.3-1).

From December 1986 to September 1987, 11 off-post surface-water sites designated by the Task 4 Final Sampling Program were sampled under the direction of the Off-post Remedial Investigation/Feasibility Study (Task 39). Task 39 was instituted to provide a remedial investigation/feasibility study program for the area north and northwest of RMA.

Following Tasks 4 and 39, on-post and off-post surface-water monitoring activities continued to be directed by Hunter/ESE under the new Task 44 contract awarded in March 1987. Task 44 operated under the core objectives of Task 4, but had broadened the scope of the program. The expanded program included monitoring changes in water quality, assessing distribution and concentration levels of contaminants, identifying areas of public exposure, and recommending modifications to the program (Hunter/ESE, 1988b). The 12 gaging stations established previously during Task 4 were used during this monitoring period. There were 40 potential on-and off-post surface-water sampling locations designated for sampling on a quarterly basis. On-post locations corresponded to the sampling sites used during Task 4. Surface-water quantity and quality data were collected during high flow events if an event fell within a designated sampling period.

Most recently as part of the Remedial Investigation program, the Water Remedial Investigation Report was created as a summary document of water-related programs at RMA. This report presents data and interpretations related to the surface-water system at RMA. Included in the document are discussions on water balances, surface/ground water interactions, and historical surface-water quality data from Fall 1985 to Fall 1987.

During FY88 water quantity was monitored by using the existing network that was established by previous contractors. The network included ten continuous recording stations, four lake stations monitored weekly and the Sewage Treatment Plant flow meter monitored weekly. Instantaneous discharge measurements were obtained at active stream stations on a monthly basis. The water quantity data base was expanded further by reviewing and refining rating curves that were developed by previous contractors for each monitoring station. During FY89 the water quantity network established during FY88 was utilized and expanded with the addition of a new station at North First Creek near the north boundary in Section 24.

Water quality samples were obtained from the existing network that was established by previous contractors. Thirty-five water sample locations were utilized from on- and off-post locations during FY88. Surface-water quality samples were collected during three separate high events at three different sample locations. Suspended load and bed load sediment samples were collected from on- and off-post locations and quantitatively and qualitatively analyzed.

During FY89 sample locations established during FY88 were utilized. Surface-water quality samples were collected from seven locations during three separate storms. Suspended load sediment samples for quantitative analysis were collected along the southern reach of First Creek. Bed load sediment samples were collected throughout RMA for qualitative analysis.

1.3.1 Surface-Water Quantity Investigations

The following discussion follows the chronology of programs and studies dealing with stage and discharge monitoring of RMA surface water. Additionally, this section describes the evolution of the surface-water gaging stations used at RMA, which is summarized in Table 1.3-2.

In 1981, under contract from Stearns-Rogers Engineering and a purchase order from Computer Science Corporation, RCI started the first comprehensive study of characteristic surface-water features at RMA. The primary purpose of the study was to provide supplemental information on surface-water features for use in other ongoing investigations. A March 1982 report suggested upgrading 2 gaging stations and adding 7 more. This report attempted a water balance calculation on the basis of estimated inflows. It recommended that a monitoring network be installed to permit calculation of a more refined water balance (RCI, 1982). The data presented in the report were derived principally from published data and hydrologic analyses of several areas surrounding RMA. Watersheds were defined and major drainages delineated. Watershed runoff estimates were computed empirically for 1971 through 1979 by using daily precipitation data obtained from the weather station located at Stapleton Airport.

Table 1.3-2 Evolution of Surface-Water Monitoring Stations

Location	Installation Date	Type	Equipment Installer	Reference
Highline Lateral	Unknown	Manometer level Recorder Cipoletti Weir	Unknown	RCI, 1983
	Spring 1982	Stevens Type F Recorder	RCI	RCI, 1983
South First Creek (old)	Spring 1982	Stevens Type F Recorder	RCI	RCI, 1983
	Sept 1988	Concrete Control Structure Abandoned	Krupke	Unknown
South First Creek (new)	Oct 1988	Concrete V-notch Weir	RLSA	
	March 1989	Stevens Type F Recorder Data Logger/Bubbler System	RLSA	
South Uvalda	Spring 1982	Stevens Type F Recorder	RCI	RCI, 1983
	1984	Concrete Control Structure	Krupke	Unknown
	March 1989	Data Logger/Bubbler System	RLSA	
Basin A	Spring 1982	Stevens Type F Recorder 90° V Notch Weir	RCI	RCI, 1983
	March 1989	Datapod Recorder	RLSA	
Ladora Weir	Spring 1982	Stevens Type F Recorder Cipoletti Weir	RCI	RCI, 1983
	March 1989	Datapod Recorder	RLSA	
North Uvalda	Spring 1982	Stevens Type F Recorder	RCI	RCI, 1983
	1983	Station Moved	RCI	RCI, 1984
	1984	Concrete Control Structure	Krupke	Unknown
	March 1989	Datapod Recorder	RLSA	
South Plants Ditch	Spring 1982	Stevens Type F Recorder Rectangular Weir	RCI	RCI, 1983
Havana Pond	Spring 1982	Staff Gage	RCI	RCI, 1983
	1984	Stevens Type F Recorder	Krupke	Unknown
	March 1989	Datapod Recorder	RLSA	
Peoria Interceptor	1983	Stevens Type F Recorder	RCI	RCI, 1984
	1984	Concrete Control Structure	Krupke	Unknown
	March 1989	Datapod Recorder	RLSA	
Havana Interceptor	1983	Stevens Type F Recorder	RCI	RCI, 1984
	March 1989	Stevens Recorder & Stilling Well Removed	RLSA	
	April 1989	Data Logger/Bubbler System	RLSA	
North First Creek (old)	1983	Stevens Type F Recorder	RCI	RCI, 1984
	Abandoned 1984	Concrete Control Structure	Krupke	Unknown
North First Creek (new)	Oct 1988	Concrete V-notch Weir	RLSA	
	March 1989	Stevens Type F Recorder Data Logger/Bubbler System	RLSA	
First Creek Off-Post	1986	H-Flume Stevens Type F Recorder	ESE	
	May 1989	Above Removed	RLSA	
	June 1989	Concrete triangular-throated flume Stevens Type F Recorder Datapod Recorder	RLSA	
Ladora Lake	Unknown	Staff Gage	Unknown	Unknown
	Unknown	Flow Meter	Unknown	Unknown
Sewage Treatment	Unknown	Flow Meter	Unknown	Unknown
Upper Derby Lake	Unknown	Staff Gage	Unknown	Unknown
Lower Derby Lake	Unknown	Staff Gage	Unknown	Unknown
Lake Mary	1985	Style C Staff Gage	ESE	Ebasco Svcs Inc., 1989

RCI = Resource Consultants Inc.
ESE = Environmental Sciences and Engineering

In the spring of 1982, RCI installed gaging stations on South First Creek, South Uvalda Interceptor, Basin A inflow, Ladora Weir, North Uvalda Interceptor (relocated) and South Plants Ditch (RCI, 1983). A staff gage was placed in Havana Detention Pond (Table 1.3-2). At this time a gaging station was being used at Highline Lateral; it had been operated historically by Shell. RMA personnel took over responsibility for the station.

Between October 1982 and September 1983, additional gaging stations were installed at Peoria Interceptor, Havana Interceptor and North First Creek. The gaging station for North Uvalda Interceptor was moved for the second time to its present location. Ten stream and ditch gaging stations were monitored during that period at RMA by Army personnel. Ladora Lake, Lower Derby Lake and Havana Pond water levels were also recorded. The primary objective of the monitoring period was to complete an accurate, Arsenal-wide, annual water balance calculated from monthly water quantity measurements. This objective however, was hampered by data gaps, principally with regard to the lakes. RCI was responsible for conducting the monthly reviews, reducing data and preparing the water balance. Rating curves were developed or updated for South First Creek, South Uvalda, Basin A inflow, and the South Plants Ditch (RCI, 1984).

From May through December of 1984, monitoring of flow and water levels at RMA was performed by Bill Krupke, who was contracted by the U.S. Army Waterways Experimental Station. Work performed during this period included installing concrete control structures at South Uvalda, North Uvalda, South First Creek, North First Creek, Peoria Interceptor, and placing a Stevens Type F station at Havana Detention Pond to use with the existing staff gage.

Hunter/ESE began managing the surface-water program under Task 4 in 1985 (Table 1.3-1). Data collected during the Task 4 Water Quantity and Quality Survey Program included water levels and flow measurements from 12 monitoring stations in place across RMA, in addition to monitoring meter readings for water taken from Ladora Lake to be used as process water, monitoring outflow discharge of effluent at the Sewage Treatment Plant, and recording water-surface elevations on Upper Derby, Lower Derby, Ladora Lake and Lake Mary. Two rain gages were installed on RMA to aid in water balance computations. Lake and pond levels were recorded weekly and stream stages were measured on a continuous basis. As part of the quantity program, rating curves were to be modified and to be extended by using Hydraulic Engineering Center (HEC-2) procedures.

The surface-water network continued to be managed by Hunter/ESE into 1987 under Task 44. Additional attempts were made to verify and extend stage-discharge rating curves for gaging locations at North and South First Creek, North and South Uvalda, Peoria Interceptor and Havana

Interceptor. The network of surface-water monitoring stations with respect to the major RMA drainage basins used during FY89 and FY88 CMP is shown on Plate 1.3-1.

During CMP FY88 data included water levels and instantaneous discharge measurements from nine monitoring stations, in addition to monitoring outflow discharge of effluent at the Sewage Treatment Plant and recording water-surface elevations on Upper Derby Lake, Lower Derby Lake, Ladora Lake, Lake Mary, and Havana Pond. Lake levels were recorded weekly and stream and pond stages were measured on a continuous basis. Rating curves generated by previous contractors were modified and extended by using HEC-2 procedures.

Other studies relating to surface-water features at RMA include drainage basin analyses by Wright Water Engineers (1988) and the U.S. Army Corps of Engineers (1983b, c, and d). Wright Water Engineers presented the results of a hydrologic analyses of First Creek and Irondale Gulch drainage basins. These analyses evaluated the hydrologic characteristics of the watersheds for existing conditions and with or without the proposed new Denver Airport. Flood peaks and volumes were defined for various recurrent storm intervals.

The U.S. Army Corps of Engineers (1983a) prepared a drainage analysis for the upper Irondale Gulch and First Creek watersheds on RMA. Flood peaks and volumes were defined for future development, analyses were conducted of flooding problems, and recommendations were made for solving on-site drainage problems. The Corps conducted inspections of the lakes and their associated dams. In 1983 the four principal lake impoundments in the South Plants area -- Havana Pond and disposal Basins C, D and F -- were inspected. During this period disposal basins C and D were not in use. Additional inspections of Havana Pond, Ladora Lake and Lower Derby Lake were performed in 1986, 1987 and 1988. The inspection reports assessed hydraulic, hydrologic, structural and geotechnical condition of the dams and impoundments. Hydraulic and hydrologic data incorporated in the reports include spillway, top of dam, and capacity rating curves.

1.3.2 Surface-Water Quality Investigations

This section provides a summary and assessment of previous RMA surface-water quality investigations. Surface-water quality data were previously collected at RMA under many programs and tasks. This section summarizes the results of and conclusions drawn from major data-collection programs, including the FY88 CMP surface-water monitoring program. The network of surface-water sampling locations with respect to the major RMA drainage basins designated in the FY88 and FY89 CMP is shown on Plate 1.3-2.

1.3.2.1 <u>360° Monitoring Program</u>. The 360° Monitoring Program was initiated in 1975 primarily to monitor on-post and off-post ground-water quality. Initially, the program included 12 on-post and 10 off-post surface-water locations. In 1983, 17 surface-water sites were sampled on a quarterly basis, and data collection activities were summarized in periodic data summaries (Ward, 1984). Most of the data collected under the program from 1979 to 1985 were incorporated into a computer database, which is discussed further in Section 1.3.2.6.

1.3.2.2 <u>Sampling Activities During the Remedial Investigation</u>. In 1985, the RMA Remedial Investigation/Feasibility Study (RI/FS) was initiated. Sampling formerly conducted under the 360° Monitoring Program was incorporated into several RI tasks. From 1985 to 1987, surface-water quality data were collected in conjunction with four RI tasks (Ebasco Services, Inc., et al., 1989a). Sixteen surface-water sites were sampled under a regional ground-water monitoring program (Task 4) from October 1985 to March 1986. As part of Task 4, 19 and 21 surface-water sites were sampled during the Third and Fourth Quarters of FY86, respectively. From December 1986 through September 1987, 11 sites were sampled under Task 39, the off-post RI. As part of the Task 44 regional monitoring program, 41 on-post and off-post surface-water sites were sampled from October 1986 to August 1987.

1.3.2.3 <u>Remedial Investigation Documentation</u>. Final documentation of the overall RI of RMA is being prepared in accordance with the proposed Federal Facility Agreement and Settlement Agreement (1988), the RMA Technical Program Plan (PMO, TPP, 1988/RIC 88131R01), and applicable RI guidance comments. Table 1.3-3 lists the reports that constitute the RI, including an overview report; reports for air, water, building, and biota media; and seven study area reports (SARs). The intent of these reports is to define the nature and extent of contamination for the On-post Operable Unit of RMA as required by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended, and the National Contingency Plan (NCP). Key findings and conclusions presented in these reports are summarized herein as they pertain to existing and/or potential surface-water contamination at RMA.

The Water Remedial Investigation (WRI) Report (Ebasco Services, Inc., et al., 1989a) represents the most recent comprehensive assessment of the RMA surface-water system. The water-quality sampling network and data used in preparing the WRI Report were generated by Tasks 4, 39, and 44. Tabular summaries of the results of previous surface-water investigations, including sampling locations, and analytical results from fall 1985 through fall 1987 were included in the WRI Report.

Table 1.3-3 RMA Remedial Investigations and Study Area Reports

Report	Volume
Overview of RMA Remedial Investigations and Study Area Reports	I
Water Remedial Investigation Report	II
Air Remedial Investigation Report	III
Biota Remedial Investigation Report	IV
Summary of Results Structures Survey Report Structure Profiles Structures Survey Report Databases Structures Survey Report	V
Southern Study Area Report	VI
Eastern Study Area Report	VII
South Plants Study Area Report	VIII
North Plants Study Area Report	IX
Central Study Area Report	X
North Central Study Area Report	XI
Western Study Area Report	XII

Source: Ebasco Services, Inc., et.al, 1989g

Data generated from the WRI effort were utilized in detailed contamination assessments of each of the seven RMA study areas. Figure 1.3-1 shows the locations of the seven RMA study areas. Pertinent conclusions relating to surface-water quality from each of the SARs are summarized in the following section.

1.3.2.4 Summary of Key Remedial Investigation Findings.

1.3.2.4.1 Southern Study Area. - According to the Southern SAR (Ebasco Services, Inc., et al., 1989b), surface water is the principal migration pathway for organochlorine pesticides, DBCP, arsenic, mercury, and ICP metals in this study area. Volatile halogenated organics, volatile aromatic organics, and organochlorine pesticides were also detected in samples of surface waters from ditches originating in the South Plants and from ditches entering RMA from the Montbello industrial and residential area to the south. Several drainage ditches from South Plants were reported to be discharging sediment in runoff containing volatile aromatic organics, semivolatile halogenated organics, organochlorine pesticides, arsenic, mercury, and ICP metals.

1.3.2.4.2 South Plants Study Area. - The South Plants Area is located on a topographic high, and surface water in this area is described in the South Plants SAR (Ebasco Services, Inc., et al., 1989c) as either locally ponded or exiting the area via a complex system of drainage ditches and storm drains. Classes of compounds detected in surface water during the RI included volatile halogenated organics, volatile hydrocarbons, volatile aromatic organic compounds, herbicide-related organosulfur compounds, GB-agent related organophosphorus compounds, DBCP, semivolatile halogenated organics, and organochlorine pesticides. The SAR documented the conclusion that surface water is a significant transport mechanism for contaminants in the South Plants Study Area.

1.3.2.4.3 Eastern Study Area. - Surface water was identified as a potential migration pathway for contaminants in the Eastern Study Area (Ebasco Services, Inc., et al., 1989h). According to the SAR, man-made drainages are located sporadically throughout this study area, and several of these drain into First Creek. Because of these source areas, the potential exists for surface runoff during storm events to carry both dissolved and suspended contaminants into First Creek. However, results from analysis of surface-water and ditch sediment samples during the RI indicated that impacts to surface water derived from activities in the Eastern Study Area are minimal (Ebasco Services, Inc., et al., 1989h).

1.3.2.4.4 Central Study Area. - The Central Study Area is described in the SAR (Ebasco Services, Inc., et al., 1989e) as a highland area with no standing water bodies present. According to this report, any surface water runoff from this area either evaporates of infiltrates before leaving the boundaries of the study area. The report indicates that although surface water and wind have

historically dispersed primarily organochlorine pesticides, arsenic, and mercury from sources in other study areas, such as Basin A to surface soils in the southwestern two-thirds of the Central Study Area, surface water is not currently a potential migration pathway in the Central Study Area.

1.3.2.4.5 North Plants Study Area. - According to the North Plants SAR (Ebasco Services, Inc., et al., 1989d), surface water generally flows east to northeast in this area and is usually confined to numerous man-made ditches. Nontarget polyaromatic hydrocarbons were tentatively identified in samples of surface soils and in samples from a main drainage; therefore, suspended and bed load sediments in surface water were identified in the SAR as transport mechanisms for this class of compounds. The SAR also indicated that surface-water transport in addition to dust, would be the primary transport mechanisms for arsenic, mercury, and ICP metals.

1.3.2.4.6 North-Central Study Area. - According to the North-Central SAR (Ebasco Services, Inc., et al., 1989f), the history of the sites in this study area indicates that surface drainage was a significant transport mechanism for potential contaminants. This study area contains Basins A, B, C, and D. The SAR reported that surface-water samples from Basin A have consistently contained organochlorine pesticides, herbicide-related organosulfur compounds, and arsenic derived from leaching of surficial soils by runoff. According to the SAR, surface-water samples from the North Bog and from First Creek (where it exits RMA) collected during the RI did not yield detections of potential contaminants, which indicated that these water bodies are not active mechanisms for transport off-post. The SAR reported that samples of surface water entering the North-Central Study Area from the South Plants Study Area have consistently contained high concentrations of volatile halogenated organics, volatile aromatic organics, volatile hydrocarbons, mustard agent-related organosulfur compounds, DBCP, organochlorine pesticides, and arsenic but that this surface water is generally contained within the basins' drainage network and does not exit RMA.

1.3.2.4.7 Western Study Area. - According to the Western Study Area SAR (Ebasco Services, Inc., et al., 1989g), surface water does not occur in this study area except as brief episodes of runoff following excessive precipitation events. Comprehensive surface-water programs have not been conducted in this study area, and the SAR documents the conclusion that surface water is not thought to be a primary migration pathway for contaminants in this study area.

1.3.2.5 Fiscal Year 1988 CMP Results. The CMP Surface-Water Technical Plan (Stollar, 1989a) describes the program for analysis of a target list of organic and inorganic chemical species. This list includes 39 organic compounds, nine metals, five anions, arsenic, mercury, cyanide, pH, specific conductance, alkalinity, and temperature. Gas chromatography/mass spectrometry (GC/MS) analyses specified in the Technical Plan were performed on samples of surface-water inflows to the

south and southeast boundaries of RMA and on a single sample of outflow of First Creek. Ten percent of all other surface-water samples were randomly selected for confirmatory analyses. The purpose of the GC/MS program was to confirm analytical results for analytes detected by target GC methods and to further characterize the quality of surface water entering RMA by identifying the presence of nontarget compounds. The analytical methods employed are summarized in the CMP Surface Water Data Assessment Report (Stollar, 1989b).

1.3.2.5.1 Surface-Water Target Organic Compounds. - Detections of surface-water target organic compounds are listed in Table 1.3-4. The geographic distributions of organic compound occurrences for FY88 are presented on Plate 1.3-3. Approximately 85 percent of the detections listed were in samples from Basin A (SW36001) and the South Plants water tower pond (SW01002). Of the 39 target list organic compounds, 11 organic compounds were not detected at any of the sampling sites. The organic compounds that were not detected in samples from any of the surface-water sites were 1,1-dichloroethane ($C_2H_4Cl_2$), 1,2-dichloroethane ($C_2H_4Cl_2$), m-xylene (C_8H_{10}), carbon tetrachloride (CCl_4), chlordane ($C_{10}H_6Cl_8$), dimethyl disulfide ($C_2H_6S_2$), dithiane ($C_4H_8S_2$), Isodrin ($C_{12}H_8Cl_6$), methylene chloride (CH_2Cl_2), oxathiane (C_4H_8SO), and dimethyl methyl phosphonate.

1.3.2.5.2 GC/MS Detections. - GC/MS analysis provided confirmation of CMP surface-water target list compound analyses and provided information on 22 additional (nontarget) compounds. Detections of these additional compounds were limited to three GC/MS results for a sample collected near Basin A (SW36001) on October 4, 1988. The three compounds detected were 1,4-dichlorobenzene (>300 μg/l), atrazine (36.4 μg/l), and supona (16.3 μg/l).

1.3.2.5.3 Trace Inorganic Constituents. - Trace constituents for which analyses were performed include arsenic, cadmium, chromium, copper, lead, mercury, and zinc. The occurrences of these constituents are presented in Table 1.3-5, and their spatial FY88 distribution at RMA is shown on Plate 1.3-4.

Arsenic was detected in samples from 15 sites, with the highest concentration of 440 μg/l reported for a sample from Basin A (SW36001). The next highest values were detected in samples collected in a number of locations along the northern boundary in the First Creek drainage. In general, the highest zinc concentrations were detected in samples collected along the southern boundary of RMA with the highest detections associated with the Havana and Peoria Interceptors monitoring stations. Mercury was detected at six sites, with all reported detections less than or equal to 0.379 μg/l. Lead was reported for only one sample. This reported detection was for a sample from the Highline Lateral South Boundary (SW08002) at a concentration of 77 μg/l. Cadmium, chromium, and copper were not detected above their respective certified reporting limits.

Table 1.3-4 Occurrence of Target Organic Compounds during CMP FY88 Sampling Activities

Site	Date	CMP Target Organic Compound	Concentration ($\mu g/l$)	Analytical Method
SW01002	21-Jun-88	Xylene (o,p)	3.30	AV8
		p,p'-DDE	4.20	KK8
		p,p'-DDT	4.80	KK8
		Dicyclopentadiene (DCPD)	15.6	P8
		Dibromochloropropane (DBCP)	2.69	AY8
		1,1-Dichloroethene	3.19	N8
		Dieldrin	3.80	KK8
		Endrin	2.70	KK8
		Chloroform	3.39	N8
		Aldrin	4.30	KK8
		Chlorophenyl Methylsulfone (CPMSO2)	9.40	AAA8
SW02005	22-Jun-88	Dieldrin	0.0946	KK8
SW02006	06-Oct-88	Chloroform	0.948	N8
		Dieldrin	0.0595	KK8
SW07003	07-Jul-88	Chloroform	0.880	N8
SW11001	16-Aug-88	Benzothiazole (BTZ)	34.3	AAA8
SW11002	16-Jul-88	Hexachlorocyclopentadiene	3.30	KK8
SW11003	15-Jun-88	Hexachlorocyclopentadiene	0.094	KK8
SW12005	19-Jul-88	Hexachlorocyclopentadiene	0.830	KK8
SW36001	15-Jun-88	Chloroform	290	N8
		1,2-Dichloroethene	9.40	N8
		Chlorobenzene	850	N8
		1,1-Dichloroethene	4.60	N8
		Benzene	56.0	AV8
Toluene	6.98		AV8	
		Ethylbenzene	29.4	AV8
		1,1,2-Trichloroethane	7.00	N8
		Tetrachloroethene	50.3	N8
		Trichloroethene	34.6	N8
		Methylisobutylketone (MIBK)	600	P8
		Dieldrin	>q.00	KK8
		Dicyclopentadiene (DCPD)	11.2	P8
		Dibromochloropropane (DBCP)	35.0	AY8
		1,1,1-Trichloroethane	1.97	N8
		Xylene (o,p)	89.0	AV8

Table 1.3-4 Occurrence of Target Organic compounds during CMP FY88 Sampling Activities (Continued)

Site	Date	CMP Target Organic Compound	Concentration (µg/l)	Analytical Method
SW36001	04-Oct-88	Dicyclopentadiene (DCPD)	60.9	P8
		Bicycloheptadiene (BCHPD)	44.0	P8
		Benzene	160	AV8
		Dieldrin	2.80	KK8
		Aldrin	1.60	KK8
		Ethylbenzene	190	AV8
		Tetrachloroethene	184	N8
		Hexachlorocyclopentadiene	2.60	KK8
		1,2-Dichloroethene	36.0	N8
		Chlorophenyl Methylsulfide (CPMS)	40.4	AAA8
		1,1-Dichloroethene	10.8	N8
		Chlorobenzene	420	N8
		Toluene	40.5	AV8
		Endrin	2.30	KK8
		Trichloroethene	112	N8
		Chlorophenyl Methylsulfoxide (CPMSO)	24.0	AAA8
		1,1,2-Trichloroethane	7.60	N8
		Chloroform	410	N8
		1,1,1-Trichloroethane	2.63	N8
		Dibromochloropropane (DBCP)	77.0	AY8
		Methylisobutylketone (MIBK)	1000	P8
		Chlorophenyl Methylsulfone (CPMSO2)	1000	AAA8
		Xylene (o,p)	290	AV8
SW37001	21-Jun-88	Dicyclopentadiene (DCPD)	9.91	P8
		Diisopropyl methyl phosphonate (DIMP)	135	F8
		Dieldrin	6.70	KK8

Table 1.3-5 Occurrence of Trace Inorganic Constituents during CMP FY88 Sampling Activities

Site ID	Sample Date	Trace Constituent	Concentration (μg/l)	Analytical Method
SW01002	21-Jun-88	Arsenic (total)	7.44	RR8
		Arsenic	19.4	RR8
		Mercury (total)	0.230	CC8
		Mercury	0.164	CC8
SW02003	14-Jun-88	Mercury (total)	0.215	CC8
		Mercury	0.158	CC8
SW02004	14-Jun-88	Arsenic (total)	3.77	RR8
		Arsenic	3.45	RR8
SW02006	06-Oct-88	Mercury (total)	0.200	CC8
SW08001	22-Jun-88	Arsenic (total)	3.23	RR8
SW08002	20-Jun-88	Lead	77.0	GG8
SW11001	20-Jun-88	Zinc (total)	31.6	GG8
SW11001	16-Aug-88	Arsenic (total)	4.74	RR8
		Arsenic	5.93	RR8
		Zinc (total)	168	GG8
		Zinc	120	GG8
SW11002	13-Jun-88	Zinc (total)	35.1	GG8
SW11002	16-Jul-88	Zinc (total)	190	GG8
		Zinc	122	GG8
SW11003	15-Jun-88	Zinc	126	GG8
SW12004	22-Jun-88	Zinc (total)	23.6	GG8
SW12004	05-Oct-88	Zinc (total)	21.8	GG8
		Zinc	23.5	GG8
SW12005	13-Jun-88	Mercury (total)	0.229	CC8
		Mercury	0.257	CC8
SW12005	19-Jul-88	Zinc	36.6	GG8

Table 1.3-5 Occurrence of Trace Inorganic Constituents during CMP FY88 Sampling Activities (Continued)

Site ID	Sample Date	Trace Constituent	Concentration ($\mu g/l$)	Analytical Method
SW24001	03-Oct-88	Arsenic (total)	26.2	AX8
		Arsenic	25.8	AX8
		Zinc (total)	25.2	GG8
		Zinc	23.0	GG8
SW24002	13-Jun-88	Arsenic (total)	3.99	RR8
		Arsenic	4.74	RR8
		Mercury (total)	0.310	CC8
SW30002	16-Jun-88	Arsenic	3.13	RR8
SW31002	21-Jun-88	Arsenic (total)	4.31	RR8
		Arsenic	3.23	RR8
SW36001	15-Jun-88	Arsenic (total)	120	RR8
		Arsenic	120	RR8
SW36001	04-Oct-88	Arsenic (total)	440	AX8
		Arsenic	420	AX8
SW37001	21-Jun-88	Arsenic (total)	5.39	RR8
		Arsenic	5.17	RR8
		Mercury (total)	0.230	CC8
		Mercury	0.379	CC8
SW37002	11-Nov-88	Arsenic (total)	280	RR8
		Zinc (total)	93.3	GG8
SW37003	11-Nov-88	Zinc (total)	33.6	GG8
SW37004	15-Nov-88	Arsenic	4.55	RR8
SW37005	15-Nov-88	Arsenic	4.31	RR8
SW37006	15-Nov-88	Arsenic	5.27	RR8
SW37007	15-Nov-88	Arsenic	20.9	RR8

1.3.2.5.4 Field Water Quality. - The field parameters measured for the 1988 Surface-Water CMP Program included temperature, pH, dissolved oxygen, specific conductance, and alkalinity. Temperatures measured in the 47 water samples ranged from 3.2 to 32 degrees Celsius (°C), with an average of 18.5°C. The pH values ranged from a low of 5.50 for a sample from Uvalda Ditch A (SW07001) to a high of 10.14 for a sample from Lake Mary (SW02004), with an overall average of 8.2. Specific conductance values ranged from a low of 50 micromhos per centimeter (μmhos/cm) for a sample from the Havana Interceptor monitoring station (SW11002) to a high of 2900 μmhos/cm for a sample from the South Plants water tower pond (SW01002), with a site-wide average of 696 μmhos/cm. Total alkalinity values ranged from a low of 118 mg/l for a sample from the Havana Pond monitoring station (SW11003) to a high of 362 mg/l for a sample from First Creek near North Plants (SW30002).

1.3.2.5.5 Major Inorganic Constituents. - The major inorganic constituents for which analyses were performed include calcium, magnesium, sodium, sulfate, nitrogen, potassium, and fluoride. The occurrence of these constituents during FY88 is summarized in Table 1.3-6. Seven of the eight highest reported values for each constituent were detected in samples from First Creek off-post monitoring locations (SW37001 and SW37002). The other area of high concentration (potassium) was the South Plants water tower pond (SW01002). The low values for most of the major inorganic constituents were reported for samples collected along the upgradient southern boundary, specifically the Peoria Interceptor monitoring station (SW11001).

1.3.2.5.6 Sediment Study. - In 1988, a preliminary sediment transport study was conducted to assess the suspended sediment quantity and bed load sediment quality in First Creek. Samples were collected from First Creek beginning at the east boundary (Section 8) to a point near December 7th Avenue in the creek (Sections 6 and 31). The total suspended solids (TSS) along this reach were quantified at 170 mg/l at SW08001, 410 mg/l at SW05002, and 1,100 mg/l at SW06001. The quantity of suspended sediment sample collected was insufficient for chemical analysis. The bed load sample analytical summary of organic compounds and trace inorganic constituents detected is provided in Table 1.3-7.

1.3.2.6 Historical Data Base for Surface-Water Quality at RMA.

1.3.2.6.1 Source. - The largest single source of surface-water quality information at RMA is currently managed by the RMA Program Manager's data management contractor, D.P. Associates (DPA), in Denver, Colorado. In an ongoing effort to assimilate and validate environmental data, DPA has obtained digital data files from the overall U.S. Army Toxic and Hazardous Materials

Table 1.3-6 Summary of Major Inorganic Constituent Occurrence During CMP FY88 Sampling Activities

	Calcium	Chloride	Fluoride	Potassium	Magnesium	Sodium	Nitrogen	Sulfate
Maximum Concentration (mg/l)	790 (SW37001)	530 (SW37001)	6.36 (SW37002)	28 (SW01002)	180 (SW37001)	510 (SW37001)	5 (SW37002)	1500 (SW37002)
Minimum Concentration (mg/l)	6.32 (SW11002)	0.969 (SW11001)	<0.482 (multiple sites)	1.93 (SW08002)	2.38 (SW11001)	0.0214 (SW11001)	6.15 (SW11001)	3.90 (SW37007)
Average Concentration (mg/l)	73.0	83.7	1.4	4.2	23.3	83.8	1.3	180

SWAR2-89.TBL

Table 1.3-7 Occurrence of Organic Compounds and Trace Inorganic Constituents in Bed Load Sediments for FY88

Site No.	Analyte Detected	Results ($\mu g/g$)
SW05002	Dichlorodiphenyltrichloroethane	0.0182
SW05002	Zinc	12.3
SW06001	Dichlorodiphenyltrichloroethane	0.0373
SW08001	Dichlorodiphenyltrichloroethane	0.0118
SW08001	Zinc	31.9
SW37002	Arsenic	7.17
SW37002	Dieldrin	0.37
SW37002	Zinc	11.8

Administration (USATHAMA) data management contractor, Potomac Research, Inc., and from other current and previous RMA contractors. Surface-water quality is only one data type being incorporated into this file.

The digital data files are accessed through a User Data Management System (UDMS) that is currently managed by DPA. The Stollar team obtained and processed a November 17, 1989, data acquisition of the surface-water quality records by modem transfer. These records will be used for subsequent comparison with results from the FY89 CMP presented in Section 4.0 of this report. More than 20,000 water-quality records representing data collected between 1979 and 1989 were analyzed as part of this effort. Data sources included (1) the 360° Monitoring Program (1979-1986), (2) Tasks 4, 39, and 44 (Ebasco Services, Inc., et al., 1989a), and (3) the CMP (1988).

1.3.2.6.2 Intended Use. - Results of the database analyses will be used for gross comparison of water-quality trends with current data. For example, the results may be useful in determining whether an analyte reported in current data is consistent with historical data.

1.3.2.6.3 Analytical Procedures. - The first analytical procedure was extraction of site data from the database corresponding to current CMP surface-water sampling sites. Site correlation was established and is summarized in Table 1.3-8. Current CMP data in the database were not used. For example, referring to Table 1.3-8, for site SW01001, data from historical sites 1DDCD and 1-001 were extracted from the database to form a historical file for that site. It should be noted that for some current CMP sites, historical correlation was not established; therefore, no historical file was created. In several cases, correlated historical and CMP sampling sites do not correspond to exactly the same sampling location. Where maps indicated that sampling sites represented measurements from locations exposed to similar environmental conditions, a correlation was drawn. All sampling locations used to construct Table 1.3-8 are shown on Plate 1.3-5. Sampling sites associated with the 360° Monitoring Program were derived from historical hand-plotted location maps. Survey coordinates were used in locating most of the CMP and Ebasco Services, Inc., (1989) sampling sites. All locations shown on Plate 1.3-5 are approximate and represent relative positions of sampling locations.

The second analytical procedure was statistical processing of historical files. Files were evaluated for number of samples, number of detections, and minimum, maximum, and average detection values. During the course of processing these files, a few anomalies in the data were noted. The number of samples reported may include duplicate data resulting from either a duplicate or diluted analysis. Information on the historical files is not sufficient to differentiate or eliminate records from the statistical treatment. Some of the historical files were coded with an "N" in a field

Table 1.3-8 Correlation of Historical and CMP FY89 Surface-Water Sampling Locations

	Station Number		
Section	360° Revisions II & II (1979-1986)	Tasks 4, 39, 44 ESE (1985-1987)	CMP (1988 - 1989)
Section 1	1DDCD	1-001	SW01001
	1BDBL	1-002	SW01002
	1CAAB	1-003	SW01003
	N	1-005	SW01004
	N	1-004	SW01005
	1BDBB	N	N
	1BDBC	N	N
Section 2	1CCBB	2-001	SW02001
	2DCDA	2-002	SW02002
	2CABB	2-007	SW02003
	N	2-008	SW02004
	N	N	SW02005
	N	N	SW02006
	N	2-003	N
	2CBBB	2-004	N
	N	2-005	N
	N	2-006	N
	2CBBC	N	N
	2DDDA	N	N
	2CAAB	N	N
Section 3	N	3-001	N
	N	3-002	N
Section 4	N	4-001	SW04001
Section 5	5DCCD	5-001	SW05001
Section 6	N	6-001	N
Section 7	7CDDC	N	SW07001
	7CCCD	7-002	SW07002
	N	7-001	N

N - denotes no correlative sampling location

Table 1.3-8 Correlation of Historical and CMP FY89 Surface-Water Sampling Locations (Continued)

	Station Number		
Section	360° Revisions II & II (1979-1986)	Tasks 4, 39, 44 ESE (1985-1987)	CMP (1988 - 1989)
Section 8	8ADDD	8-001	SW08001
	8CCCD	8-002	SW08002
	N	N	SW08003
	8AAAC	N	N
Section 11	11CCD(D)	11-001	SW11001
	11CCC(B)	11-002	SW11002
	N	11-004	SW11003
	11BDC(D)	11-003	N
Section 12	N	N	SW12001
	N	N	SW12002
	N	12-003	SW12003
	N	12-004	SW12004
	12DCC(D)	12-005	SW12005
	N	N	SW12006
	N	N	SW12007 (replaces SW07003)
	12DDD(D)	N	N
	N	12-001	N
	12CDD(D)	12-002	N
	N	12-006	N
Section 13	12CCB(C)	N	N
	13DCC	13DCC	N
Section 14	14BDD(D)	14BDD	SW37001
Section 24	24ACC(C)	24-001	SW24001(F)*
	N	N	SW24001(S)**
	24ABB(B)	24-002	SW24002
	24BBB(D)	24-008	SW24003
	N	N	SW24004
	N	24-003	N
	N	24-004	N

N - denotes no correlative sampling location

* SW24001(F) - indicates sample collected in fall 1988
** SW24001(S) - indicates sample collected in spring 1988
Spring and fall samples for 24001 were collected at different locations during FY88

Table 1.3-8 Correlation of Historical and CMP FY89 Surface-Water Sampling Locations (Continued)

	Station Number		
Section	360° Revisions II & II (1979-1986)	Tasks 4, 39, 44 ESE (1985-1987)	CMP (1988 - 1989)
Section 24 (Con't)	N	24-005	N
	N	24-006	N
	N	24-007	N
Section 26	26CDB(A)	26-001	N
Section 30	N	30-001	SW30001
	30BCC(C)	30-002	SW30002
Section 31	N	N	SW31001
	31DBD(C)	31-002	SW31002
	N	31-001	N
	N	31-003	N
Section 35	N	35-001	N
	N	35-002	N
	N	35-003	N
Section 36	36CCD(C)	36-001	SW36001
	N	36-002	N
	N	36-003	N

N - denotes no correlative sampling location

designated for validity. The field is no longer used, and the representation of the qualifier is unknown (personal communication with Mr. James Clark of DPA, 1984); therefore, the historical files may contain ambiguous data. The results of the statistical treatment of the historical files are presented in Tables 1.3-9 and 1.3-10. The minimum values generally reflect the lowest certified reporting limit (CRL) for a given analyte. Tables 1.3-9 and 1.3-10 allow for comparison of the range of occurrence of a given organic or inorganic analyte, respectively, at a given site with current data. The type of analysis for a given analyte was not differentiated; therefore, statistics for occurrence of analytes may be based on several analytical methods. Average concentrations of analytes were based on only values above the detection limit(s) at a given site.

1.3.2.6.4 Evaluation. - Tables 1.3-9 and 1.3-10, which were compiled from the comprehensive database, provide an indication of historical organic compound and trace inorganic constituent detections reported in the database. Trace inorganic constituents are defined as those generally occurring at concentrations less than 0.1 mg/l in natural waters. A total of 311 organic compound detections and 89 trace inorganic detections in surface-water are reported historically for sites corresponding to CMP surface-water sampling sites. It should be noted that current FY89 CMP data and data from historical sites not corresponding to current CMP sites were not included in the analysis.

As shown in Table 1.3-9, 35 organic compounds were detected historically at current CMP surface-water sampling sites. Compounds detected historically at three or more current CMP sites are listed chronologically as follows, according to the number of sites at which a compound was detected:

Compound	No. of Sites
DBCP	11
Chloroform (CHCL3)	10
Dieldrin (DLDRN)	7
Aldrin (ALDRN)	6
DIMP	7
Chlorophenyl methylsulfone (CPMSO2)	6
Dicyclopentadiene (DCPD)	6
Benzothiazole (BTZ)	4
Chlorophenyl methylsulfoxide (CPMSO)	4
Hexachlorocyclopentadiene (CL6CP)	4
Benzene (C6H6)	3
Chlorophenyl methylsulfide (CPMS)	3
Endrin (ENDRN)	3

Table 1.3-9 Historical Organic Compound Detections at Current CMP Surface-Water Sites (in $\mu g/l$)[a]

CMP Site	Analyte[b]	No. of Samples	No. of Detections	Minimum	Maximum	Average[c]
SW01001	DBCP	21	1	<0.13	4.41	4.4
SW01002	11DCE	5	1	<1.10	3.19	3.2
	ALDRN	6	2	<0.070	4.30	2.4
	BTZ	2	1	<5.0	18.4	18
	C6H6	5	1	<1.05	1.98	2.0
	CHCL3	6	2	<1.40	87.0	45
	CL6CP	5	1	<0.048	0.308	0.31
	CPMS	6	2	<1.30	53.0	28
	CPMSO	6	3	<4.20	200	88
	CPMSO2	4	3	<20.0	290	130
	DBCP	6	4	<0.130	25.3	7.4
	DCPD	6	2	<9.31	20.7	18
	DLDRN	6	5	<0.0539	3.80	1.3
	ENDRN	6	2	<0.052	2.70	1.7
	ISODR	6	1	<0.051	1.19	1.2
	MEC6H5	5	2	<1.21	8.37	4.9
	PPDDE	6	1	<0.046	4.20	4.2
	PPDDT	6	1	<0.059	4.80	4.8
	XYLEN	5	1	<2.47	3.30	3.3
SW01003‡	ALDRN	14	3	<0.20	0.24	0.12
	CHCL3	9	7	<1.00	421	86
	CPMSO2	9	1	<4.70	31.3	31
	DBCP	30	30	0.285	114	6.9
	DCPD	8	1	<1.00	3.00	3.0
	DLDRN	13	5	<0.20	2.53	0.67
	ENDRN	15	2	<0.20	0.0805	0.06
SW02002	DBCP	22	4	<0.20	4.85	1.5
	DCPD	16	4	<1.00	712	220
	DIMP	22	3	<2.00	303	140
SW02003	CHCL3	8	6	<0.50	114	27
	PPDDE	6	1	<0.053	0.03	0.03
SW02005‡	DLDRN	1	1	0.0946	0.0946	0.095
SW02006	CHCL3	1	1	0.948	0.948	0.95

[a] Based on the November 17, 1989, data acquisition from the UDMS, as managed by D.P. Associates, and historical site correlation, as provided in Table 1.3-6

[b] See list of abbreviations and acronyms for full chemical name

[c] Based only on samples in which the detected concentration was above the detection limit

‡ May contain data of questionable concentration when above the detection limit

< below detection limit

Table 1.3-9 Historical Organic Compound Detections at Current CMP Surface-Water Sites (in $\mu g/l$)[a] (Continued)

CMP Site	Analyte[b]	No. of Samples	No. of Detections	Minimum	Maximum	Average[c]
	DLDRN	1	1	0.0595	0.0595	0.060
SW05001	CHCL3	7	1	<0.50	6.00	6.0
SW07002	DIMP	25	1	<2.0	10.1	10
SW08001‡	ALDRN	2	1	<0.050	0.162	0.16
	DBCP	29	3	<0.13	11.4	3.9
SW08002	DBCP	14	1	<0.13	0.31	0.31
	DIMP	13	1	<2.00	127	130
SW11001‡	111TCE	14	2	<1.00	2.93	2.3
	ALDRN	12	1	<0.050	0.245	0.24
	BTZ	6	4	<5.00	34.3	15
SW11002‡	BTZ	8	1	<1.14	9.34	9.3
	CL6CP	11	1	<0.048	3.30	3.3
SW11003‡	BTZ	4	2	<5.00	2.06	2.1
	CPMSO	7	1	<1.98	32.7	33
	CPMSO2	7	1	<2.24	>q00	>q00
SW12005	C6H6	9	1	<1.00	3.03	3.0
	CL6CP	8	1	<0.048	0.830	0.83
	TCLEE	9	1	<0.750	2.66	2.7
	TRCLE	9	1	<0.560	7.52	7.5
SW12007	CHCL3	1	1	0.880	0.880	0.88
SW24001‡	ALDRN	7	3	<0.050	0.598	0.40
	CHCL3	9	2	<0.500	9.66	7.3
	DBCP	28	16	<0.13	387	36
	DIMP	10	1	<10.5	2.86	2.9
	DLDRN	8	4	<0.050	0.936	0.33
SW24002	DBCP	36	1	<0.195	1.50	1.5
	DIMP	28	2	<10.0	59.3	36

a Based on the November 17, 1989, data acquisition from the UDMS, as managed by D.P. Associates, and historical site correlation, as provided in Table 1.3-6

b See list of abbreviations and acronyms for full chemical name

c Based only on samples in which the detected concentration was above the detection limit

‡ May contain data of questionable concentration when above the detection limit

< below detection limit

Table 1.3-9 Historical Organic Compound Detections at Current CMP Surface-Water Sites (in $\mu g/l$)[a] (Continued)

CMP Site	Analyte[b]	No. of Samples	No. of Detections	Minimum	Maximum	Average[c]
	TRCLE	3	1	<0.560	35.5	36
SW24003‡	CHCL3	4	1	<0.500	1.00	1.0
	CPMS	5	1	<1.08	7.00	7.0
	CPMSO	5	1	<1.98	72.0	72
	CPMSO2	5	1	<2.24	35.0	35
	DBCP	42	21	<0.13	15.1	4.0
	DCPD	18	2	<1.00	2030	1020
	DIMP	25	14	<2.00	321000	23000
SW31002‡	CHCL3	8	2	<0.500	3.54	2.8
SW36001‡	111TCE	8	5	<1.00	3.25	2.6
	112TCE	8	6	<1.00	7.60	5.1
	11DCE	8	6	<1.00	10.8	5.5
	12DCE	8	6	<1.20	36.0	13
	ALDRN	6	3	<0.700	13.7	5.4
	ATZ	1	1	36.4	36.4	36
	BCHPD	2	1	<5.90	44.0	44
	C6H6	7	6	<1.00	180	78
	CH2CL2	8	1	<1.00	7.85	7.8
	CHCL3	7	6	<1.00	561	360
	CL6CP	4	1	<1.40	2.60	2.6
	CLC6H5	7	7	15.8	1750	760
	CPMS	7	6	<5.69	44.3	29
	CPMSO	8	7	<11.5	87.1	47
	CPMSO2	6	5	<7.46	1000	590
	DBCP	20	19	<26.0	179	74
	DCPD	9	6	<1.00	70.2	34
	DIMP	21	1	<1.00	32.3	32
	DLDRN	5	4	<4.70	>20.0	10
	DMMP	7	1	<15.2	17.3	17
	ENDRN	5	3	<1.00	7.22	4.9
	ETC6H5	7	5	<1.00	190	65
	ISODR	7	1	<0.510	1.45	1.4
SW36001‡	MEC6H5	7	5	<1.00	40.5	18
	MIBK	5	4	<1.40	1000	490
	OXAT	8	1	<1.35	27.0	27

[a] Based on the November 17, 1989, data acquisition from the UDMS, as managed by D.P. Associates, and historical site correlation, as provided in Table 1.3-6

[b] See list of abbreviations and acronyms for full chemical name

[c] Based only on samples in which the detected concentration was above the detection limit

‡ May contain data of questionable concentration when above the detection limit

< below detection limit

Table 1.3-9 Historical Organic Compound Detections at Current CMP Surface-Water Sites (in $\mu g/l$)[a] (Continued)

CMP Site	Analyte[b]	No. of Samples	No. of Detections	Minimum	Maximum	Average[c]
	PPDDT	7	1	<0.490	54.7	55
	SUPONA	1	1	16.3	16.3	16
	TCLEE	9	9	43.1	184	100
	TRCLE	8	7	<1.00	112	53
	XYLEN	6	6	89.0	290	170
SW37001‡	12DCLE	7	1	<0.610	0.754	0.75
	CPMSO2	9	1	<4.66	5.20	5.2
	DBCP	22	1	<0.130	0.550	0.55
	DCPD	15	6	<9.31	178	67
	DIMP	20	20	10.0	1790	460
	DITH	9	2	<1.10	2.76	2.5
	DLDRN	8	1	<0.060	6.70	6.7

a Based on the November 17, 1989, data acquisition from the UDMS, as managed by D.P. Associates, and historical site correlation, as provided in Table 1.3-6

b See list of abbreviations and acronyms for full chemical name

c Based only on samples in which the detected concentration was above the detection limit

‡ May contain data of questionable concentration when above the detection limit

< below detection limit

Table 1.3-10 Historical Trace Inorganic Constituent Detections at Current CMP Surface-Water Sites (in $\mu g/l$)[a]

CMP Site	Analyte[b]	No. of Samples	No. of Detections	Minimum	Maximum	Average[c]
SW01001‡	As	5	1	<2.35	2.56	2.6
SW01002	As	4	4	7.44	290,000	26,000
	Hg	3	2	<0.500	0.23	0.20
	Zn	3	1	<22.0	40.0	40
SW01003	As	7	4	<50.0	344,000	86,000
SW02002	As	3	1	<2.50	21.8	22
SW02003	Hg	4	2	<0.020	0.215	0.19
SW02004‡	As	3	2	<3.07	3.77	3.6
	Zn	3	1	<22.0	78.8	79
SW02006	Hg	2	1	<0.100	0.200	0.20
SW05001‡	As	5	1	<2.50	3.78	3.8
SW07002‡	Cr	6	1	<5.96	18.2	18
	Pb	6	1	<18.6	41.3	41
SW08002‡	Pb	3	1	<18.6	77.0	77
	Zn	3	1	<22.0	74.5	74
SW11001‡	As	9	3	<2.35	5.93	5.1
	Zn	9	5	<20.1	168	85
SW11002‡	As	11	1	<2.35	4.20	4.2
	Cr	11	1	<5.96	48.7	49
	Cu	12	2	<7.93	12.7	12
	Pb	12	1	<18.6	76.0	76
	Zn	7	5	<20.1	190	120
SW11003‡	Zn	3	1	<20.1	126	130
SW12004‡	As	3	1	<2.35	3.78	3.8
	Cu	5	1	<26.0	13.2	13
	Zn	5	3	<22.0	28.8	25

[a] Based on the November 17, 1989, data acquisition from the UDMS, as managed by D.P. Associates, and historical site correlation, as provided in Table 1.3-6

[b] See list of abbreviations and acronyms for full chemical name

[c] Based only on samples in which the detected concentration was above the detection limit

‡ May contain data of questionable concentration when above the detection limit

< below detection limit

Table 1.3-10 Historical Trace Inorganic Constituent Detections at Current CMP Surface-Water Sites (in $\mu g/l$)[a] (Continued)

CMP Site	Analyte[b]	No. of Samples	No. of Detections	Minimum	Maximum	Average[c]
SW12005	Hg	7	2	<0.100	0.257	0.24
	Zn	6	1	<20.1	36.6	37
SW24001‡	As	6	5	<2.50	38.7	25
	Zn	4	2	<22.0	150	90
SW24002	As	3	2	3.99	4.74	4.4
	Hg	2	1	<0.100	0.310	0.31
SW24003‡	As	5	1	<2.250	2.56	2.6
	Zn	4	1	<20.1	162	160
SW30002‡	As	3	1	<2.50	3.13	3.1
SW31002‡	As	7	5	<3.07	7.27	4.5
SW36001‡	As	7	7	120	440	290
SW37001‡	As	8	5	<3.07	9.04	5.3
	Cr	8	1	<5.96	11.5	12
	Hg	8	2	<0.240	0.379	0.30
	Zn	8	2	<20.1	29.5	26

[a] Based on the November 17, 1989, data acquisition from the UDMS, as managed by D.P. Associates, and historical site correlation, as provided in Table 1.3-6

[b] See list of abbreviations and acronyms for full chemical name

[c] Based only on samples in which the detected concentration was above the detection limit

‡ May contain data of questionable concentration when above the detection limit

< below detection limit

Compounds detected at only two sites included the following:

1,1,1-Trichloroethane (111TCE)
1,1-Dichloroethene (11DCE)
DDE (PPDDE)
DDT (PPDDT)
Isodrin (ISODRN)
Tetrachloroethene (TCLEE)
Toluene (MEC6H5)
Trichloroethene (TRCLE)
Xylene (XYLEN)

Compounds detected at only one site included the following:

1,1,2-Trichloroethane (112TCE)
1,2-Dichloroethane (12DCLE)
1,2-Dichloroethene (12DCE)
Atrazine (ATZ)
Bicycloheptadiene (BCHPD)
Chlorobenzene (CLC6H5)
Dimethyl methyl phosphonate (DMMP)
Dithiane (DITH)
Ethylbenzene (ETC6H5)
Methylene chloride (CH2CL2)
Methylisobutylketone (MIBK)
Oxathiane (OXAT)
Supona (Supona)

The frequency of historical organic compound detections is provided on Plate 1.3-6, which includes the surface-water sampling location, organic compound, and the frequency at which the compound was detected historically.

As indicated on Plate 1.3-6 and Table 1.3-9, Basin A (SW36001) and the South Plants sedimentation pond site (SW01002) have historical detections of a wide range of compounds, with 31 and 18 compounds detected, respectively. The North Bog (SW24003), First Creek Off-Post monitoring station (SW37001), and South Plants Ditch monitoring station (SW01003) have historical detections of seven compounds each, and the Sewage Treatment Plant effluent site (SW24001) has historical detections of five compounds. The South Uvalda Interceptor monitoring station (SW12005) has

historical detections of four compounds. All other sites shown on Plate 1.3-6 have historical detections of three compounds or fewer.

As indicated in Table 1.3-10, six trace inorganic constituents were detected historically at current CMP surface-water sampling sites. Constituents detected historically at three or more current CMP sites are listed in order of number of sites detected as follows:

Constituent	No. of Sites
Arsenic (As)	16
Zinc (Zn)	11
Mercury (Hg)	6
Chromium (Cr)	3
Lead (Pb)	3

Copper (Cu) was the constituent detected at only two sites.

The frequency of historical trace inorganic constituent detections is provided on Plate 1.3-7, which includes the surface-water sampling location, trace inorganic constituent, and the frequency at which the constituent was detected historically.

As indicated on Plate 1.3-7, the Havana Interceptor (SW11002) and First Creek Off-Post monitoring station (SW37001) have historical detections of a wide range of trace inorganic constituents, with five and four constituents detected respectively. All other sites shown on Plate 1.3-7 have historical detections of three or fewer constituents.

Analytical results in the historical database that are presented in this section will be further reviewed in Section 5.0, Data Assessment, and will be compared with current FY89 CMP data, as appropriate.

The utility of the database for assessment purposes is dependent on the quality of the data contained therein and the ability to accurately establish previous sampling locations and correlate them with current and future monitoring networks. Management of the database through time, including data validation, ensuring data completeness, and documentation of updates and procedures, has been the responsibility of USATHAMA and/or RMA Program Manager's data management contractors. At this time, the exact correlation that exists between current CMP sites and the site designations in the database had not been definitely established. In addition, outstanding records from previous monitoring programs have not been included in the database. Records from Hunter-ESE (677) and

records from Ebasco, Inc., (1218) are currently being checked and processed before their inclusion into the database.

Results of the historical analysis presented above were compared with the similar analysis performed for the FY89 report to assess the comparability of the results. The primary differences are an increase in the number of samples and/or detections and additional analytes and/or sites. Minor differences occurred in either the number of detections or the minimum/maximum reported for a given site. The differences most likely result from the ongoing effort by DPA to include only validated data in its compilation of the RMA database. Additionally, DPA recalculated all the data to correct the data discrepancies that resulted from the use of former Installation Restoration Database Management System (IRDMS) software programs (personal communication with Mr. James Clark of DPA, 1989).

1.3.3 Sediment Transport

Sediment transport is a potential pathway for contaminants in the surface-water system at RMA. Contaminants may be adsorbed onto sediment particles and transported as suspended load or bed load in the drainages. Limited data exist to evaluate the magnitude of the flow of low solubility contaminants such as heavy metals, pesticides and semi-volatile organics through the surface-water system. Sediment loading in RMA drainages can be a significant factor that influences aquatic habitat and channel evolution.

The WRI Report (Ebasco Services, Inc., et al., 1989a) identified mechanisms for mobilizing contaminants into RMA surface water. Some qualitative or quantitative evaluation was performed during FY88 to ascertain the role of sediment transport in the movement of contaminants in RMA surface water. As part of the 1988 sampling program, bed load and suspended load sediment samples were collected on First Creek. Preliminary results of the initial sampling effort were presented in the FY88 report. As part of the 1989 sampling program bed load sediment samples were collected at various sampling locations throughout RMA for qualitative analysis. During the FY89 sampling program suspended load sediment samples were collected on First Creek for quantitative analysis.

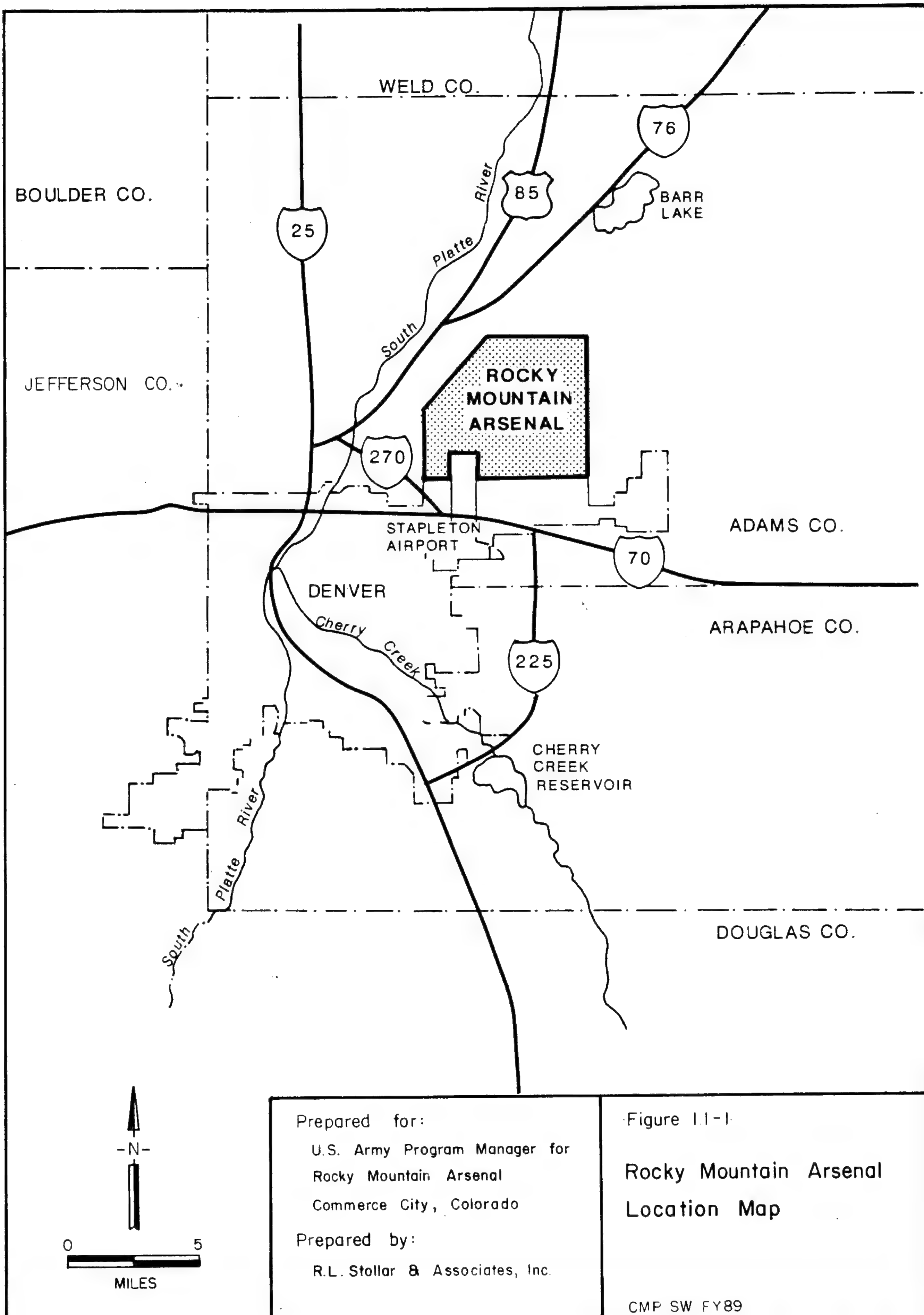
1.3.4 Ground-Water and Surface-Water Relationships

To monitor the pathways by which contaminants may be entering or moving off RMA, it is important to assess the relationship between the surface- and ground-water systems, and specifically to assess the potential for discharge of contaminated ground water to surface water.

Previous attempts were made to verify areas of surface- and ground-water interaction. Initial studies which tried to quantify gain-loss relationship between surface- and ground-water systems were conducted by RCI (1982, 1983, 1984 and 1987). These studies emphasized gain-loss calculations for the South Plants Lakes. In a one month water balance calculation for March, 1987 (RCI, 1987), areas of ground-water discharge were identified at Ladora Lake and Lake Mary. Ground water appeared to be recharged by surface water at Havana Pond and along Uvalda Interceptor. Water balance calculations in the lakes area could not be totally substantiated because it was uncertain whether all components had been addressed. It was noted that there were unaccounted inflows, such as potable water releases and actual precipitation to the lakes. Unmeasured outflow occurred in Lake Mary and Ladora Lake in the form of bank seepage and discharge through overflow outlets. Water balance calculations conducted by RCI were considered preliminary. Further data need to be collected to verify initial computations.

Under the Task 4 and 44 programs conducted by Hunter/ESE (1988a and 1988b), additional stream flow and ground-water level information was gathered to delineate areas of gain or loss to the surface-water system. The WRI Report (Ebasco Services, Inc., et al., 1989a) interpreted data available up to 1987 and indicated locations and estimated values of recharge and discharge between surface-water bodies and the unconfined ground-water system. Water balance calculations were completed for the lakes area. Gain-loss volumes were considered approximate because of a number of unmeasured variables in the calculations. Extrapolation of water-table contours from monitoring wells located near surface-water bodies in conjunction with comparisons to long-term hydrographs substantiated recharge-discharge relationships. RMA areas of interest to the CMP surface-water monitoring program that have historically indicated a net discharge from ground water include Ladora Lake, Lake Mary and Upper Derby Lake (when dry). Areas displaying a net loss to the ground-water system include First Creek, Lower Derby Lake, Upper Derby Lake (when filled with water), Havana Pond and Uvalda Interceptor (Ebasco Services, Inc., et al., 1989a).

During the first year of the CMP surface-water program, available data were used to evaluate surface-ground water interaction in the South Plants Lakes area, Havana Pond, along Uvalda Interceptor and along First Creek (see FY88 report). The data presented in the FY88 report suggested that surface water on RMA is interconnected with ground water. Hydrograph data indicated similar water elevations in the South Plants Lakes, Havana Pond and nearby wells. An ionic comparison of First Creek and nearby wells showed that surface water and ground water is similar in ionic character and proportion. During FY89 , South Plants Lakes and First Creek areas were studied. Hydrographs, and organic and ionic chemical composition comparisons are presented in Section 4.4.



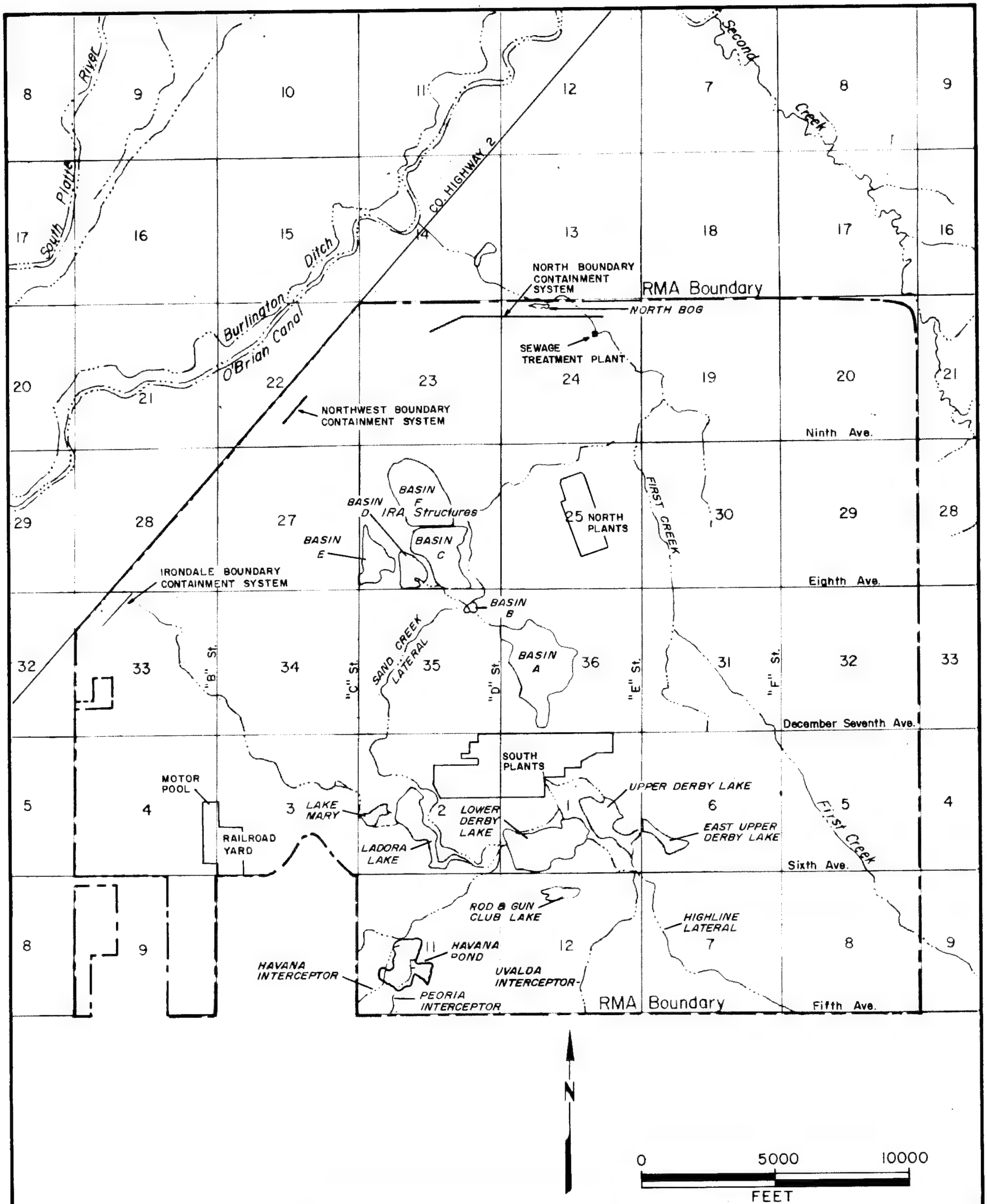
Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.

Figure 1.1-1

Rocky Mountain Arsenal
Location Map

CMP SW FY89



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U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

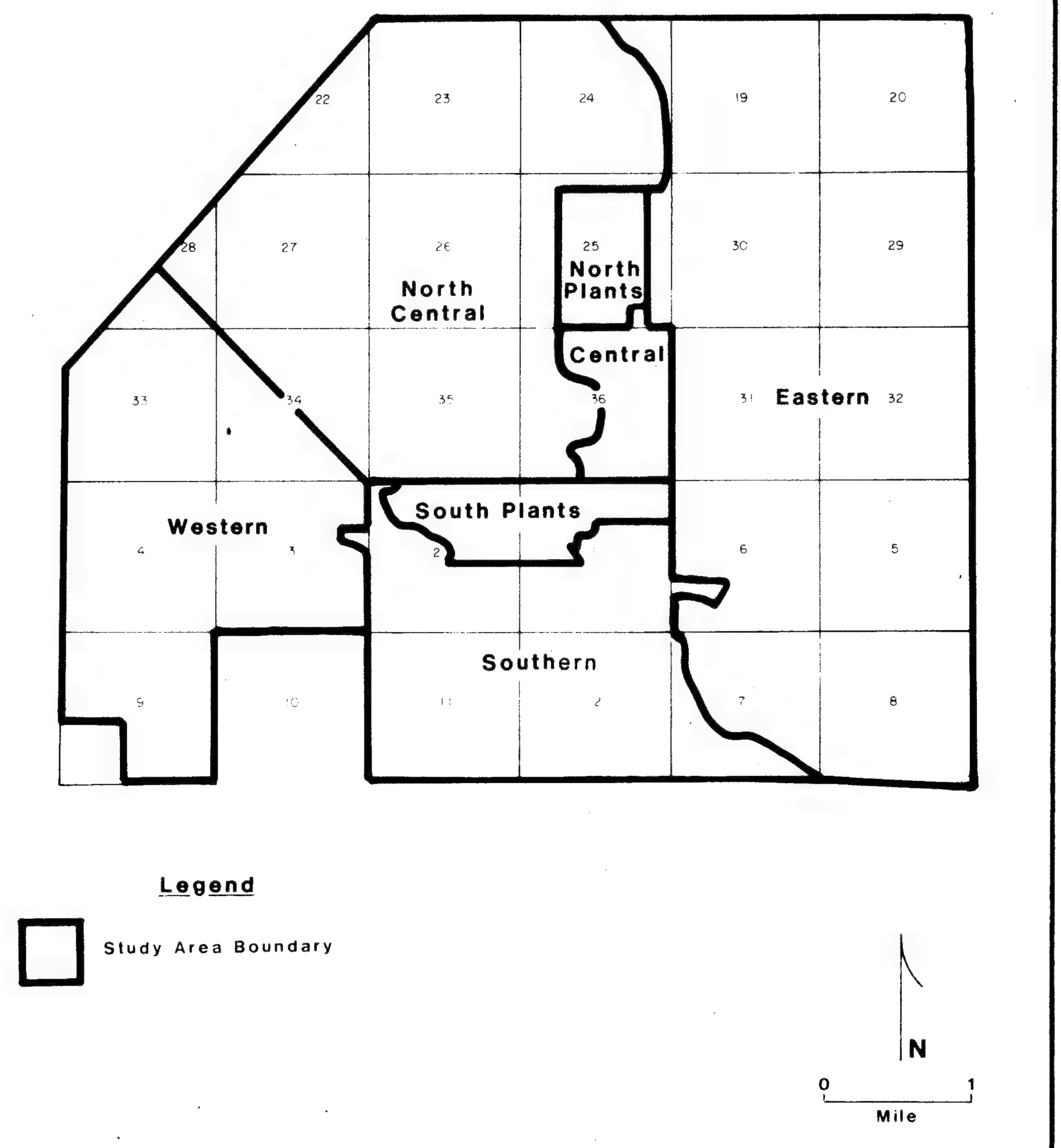
Prepared by:

R.L. Stollar & Associates, Inc.
Harding Lawson Associates

Figure 1.1-2

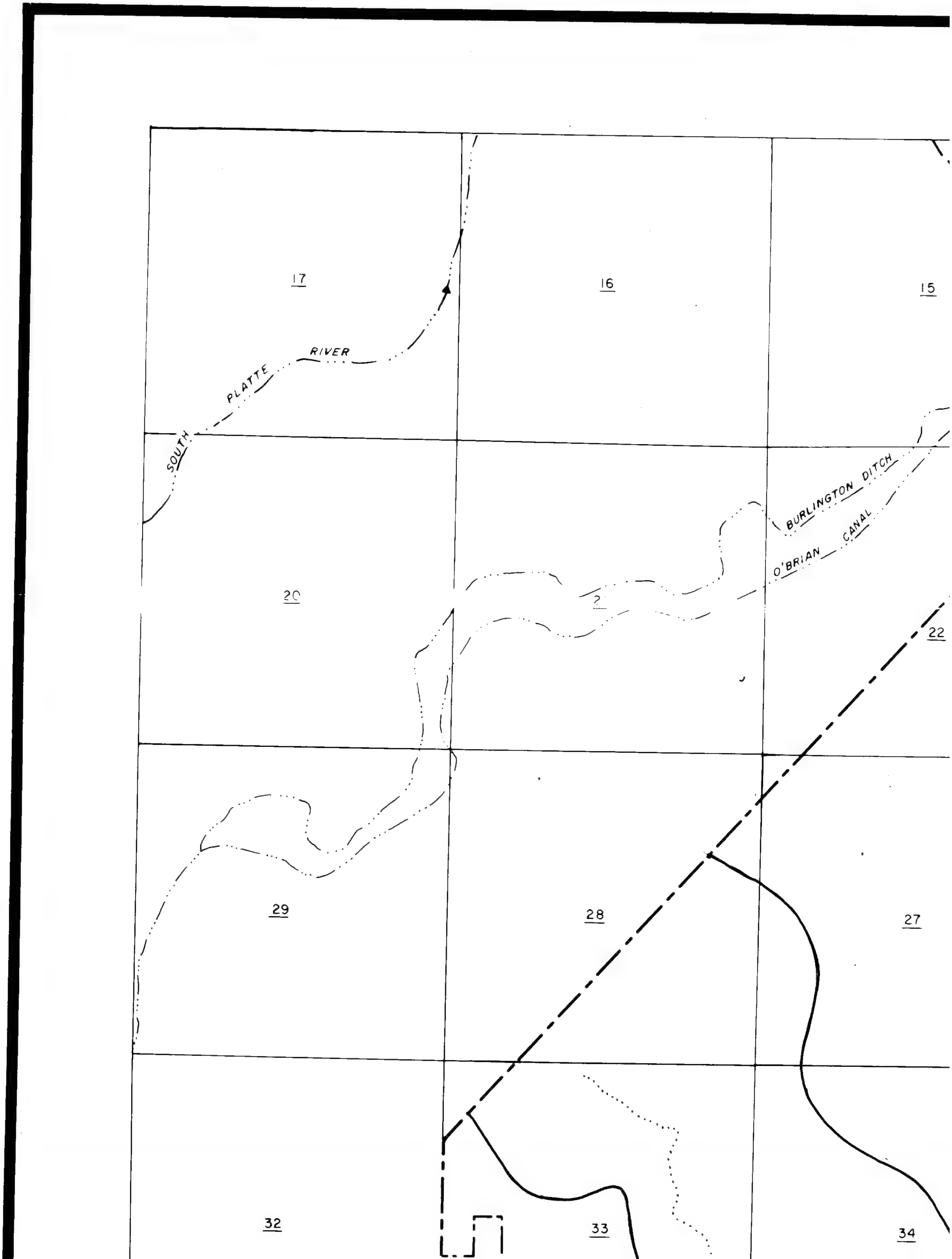
Rocky Mountain Features Map

CMP SW FY89

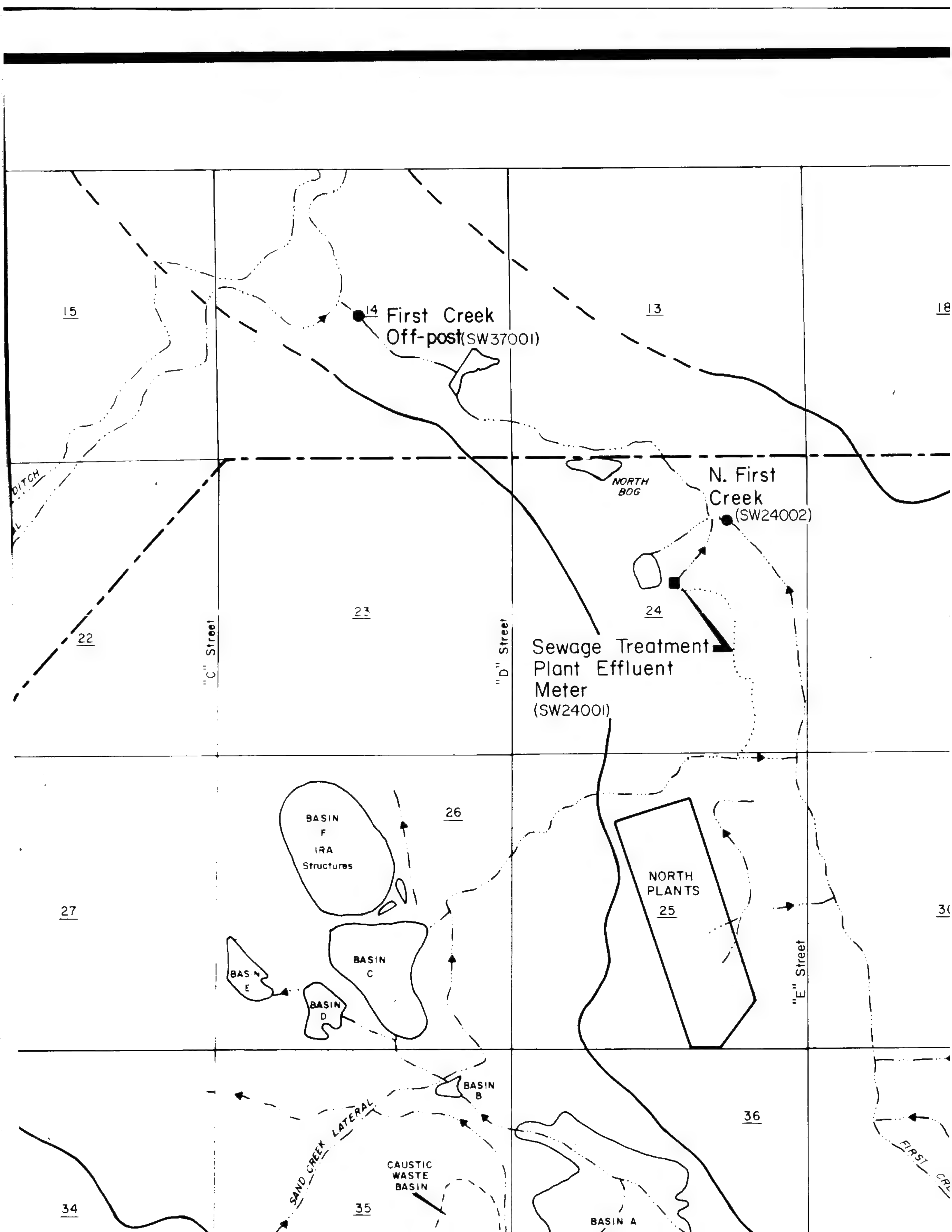


Source: Ebasco, 1989

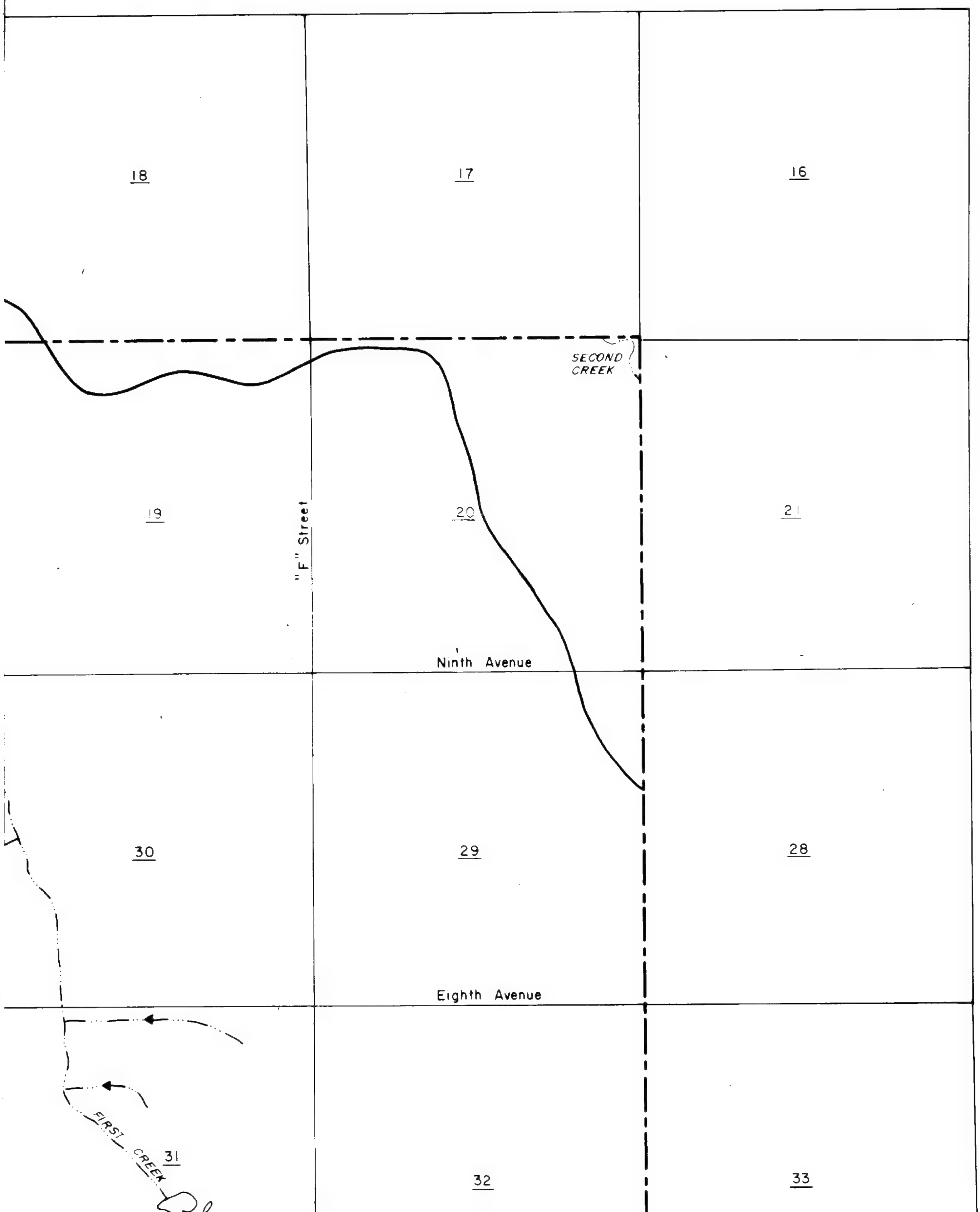
Prepared for: Program Manager's Office for Rocky Mountain Arsenal Cleanup Commerce City, Colorado	FIGURE 1.3-1 Locations of Study Areas Rocky Mountain Arsenal Prepared by: R.L. Stollar & Associates, Inc. **CMP SW FY89**



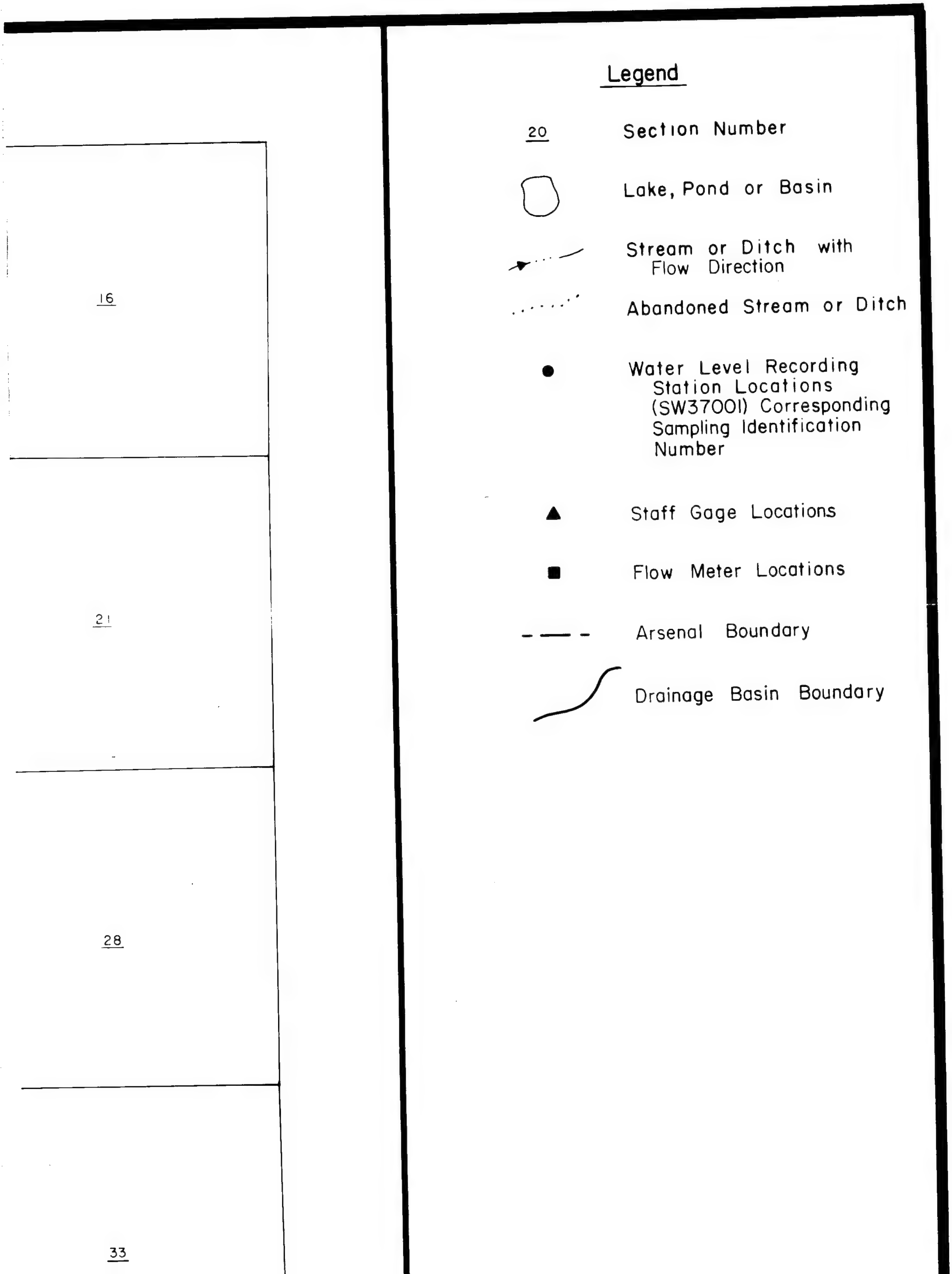
17
16
15
SOUTH PLATTE RIVER
BURLINGTON DITCH
O'BRIAN CANAL
20
22
29
28
27
32
33
34

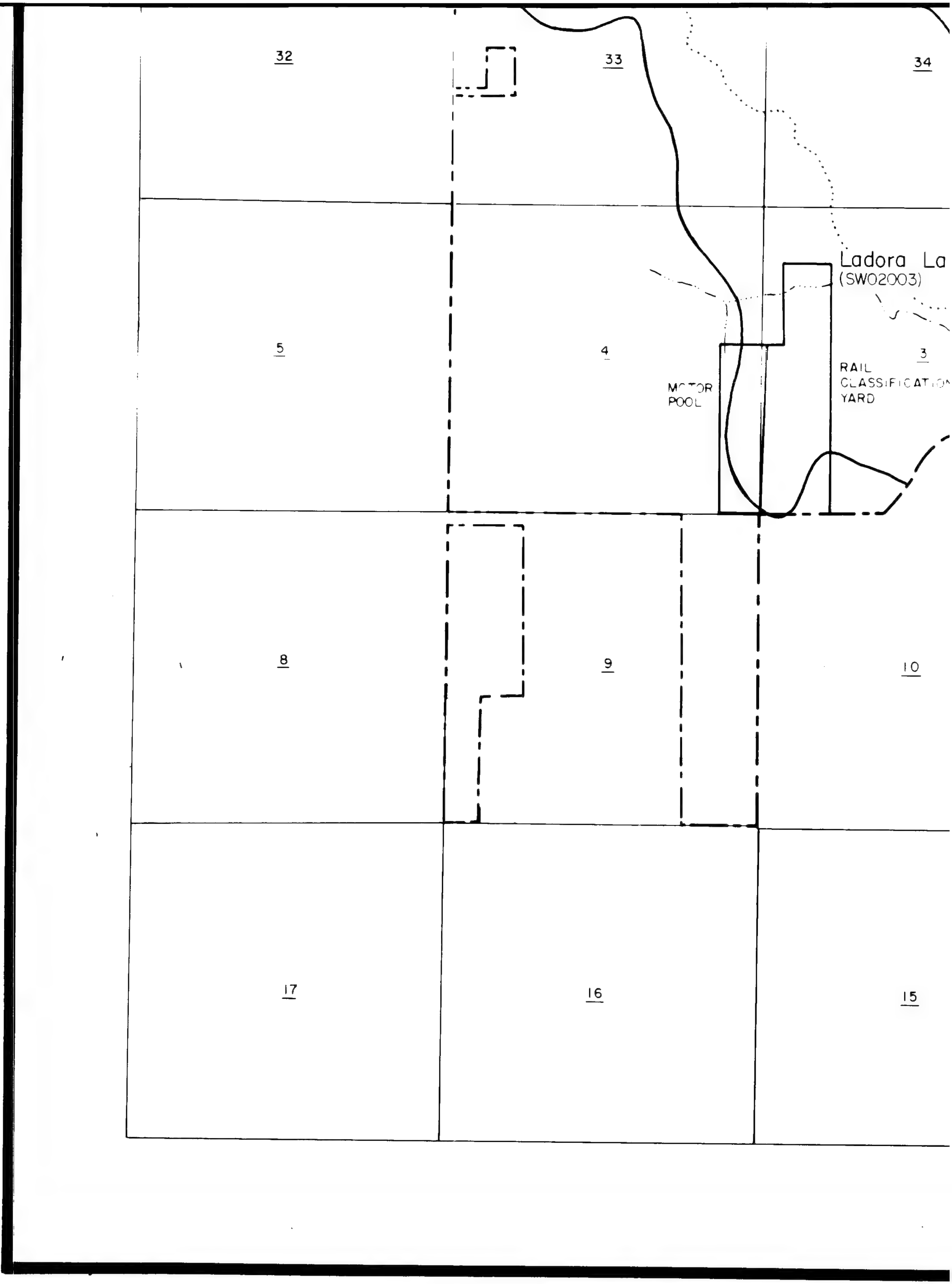


15
14
First Creek
Off-post (SW37001)
13
18
DITCH
NORTH BOG
N. First Creek
(SW24002)
22
"C" Street
23
"D" Street
24
Sewage Treatment
Plant Effluent
Meter
(SW24001)
BASIN F IRA Structures
26
27
NORTH PLANTS
25
30
BASIN C
BASIN E
BASIN D
"E" Street
BASIN B
SAND CREEK LATERAL
36
FIRST CR
CAUSTIC WASTE BASIN
34
35
BASIN A

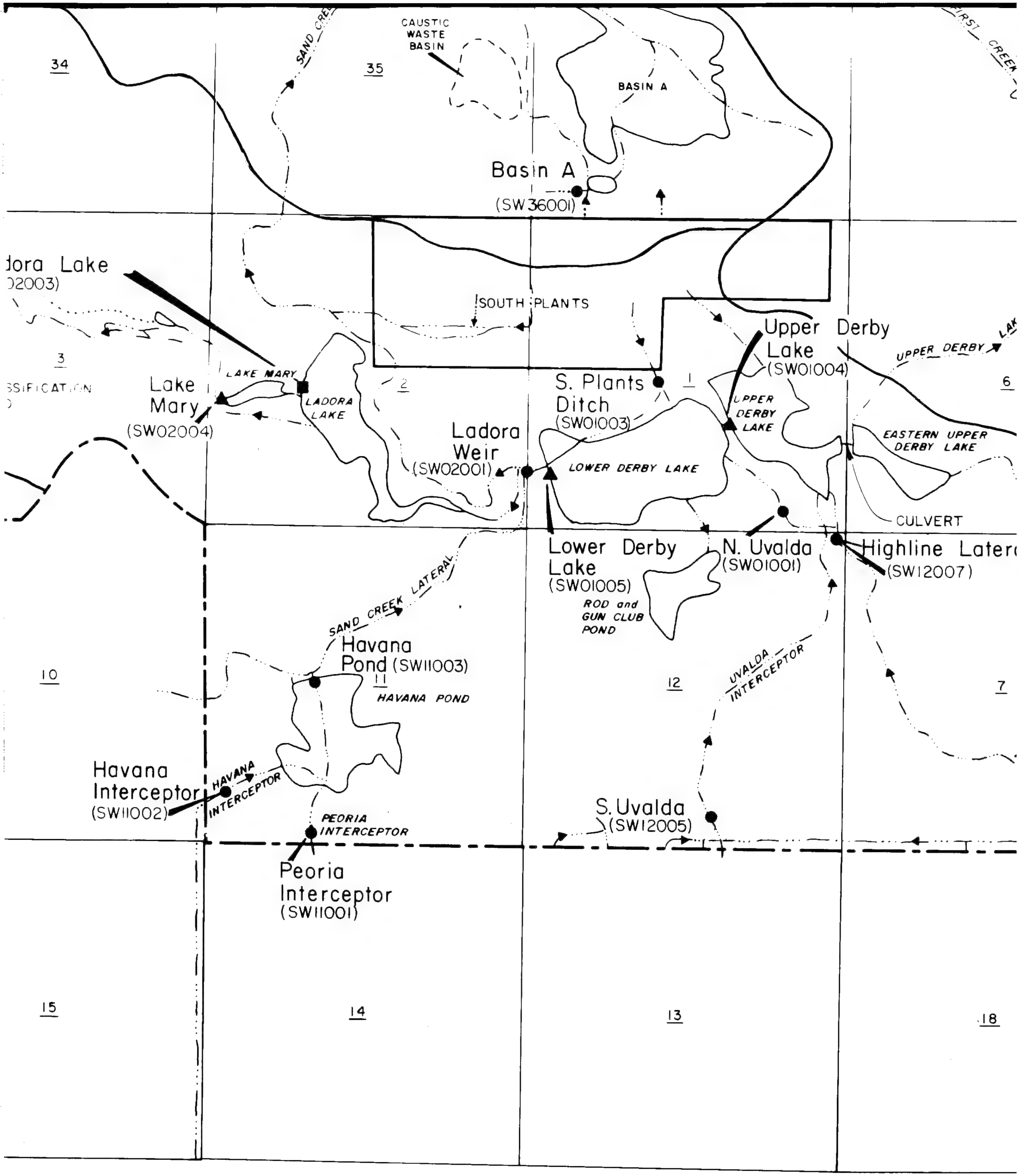


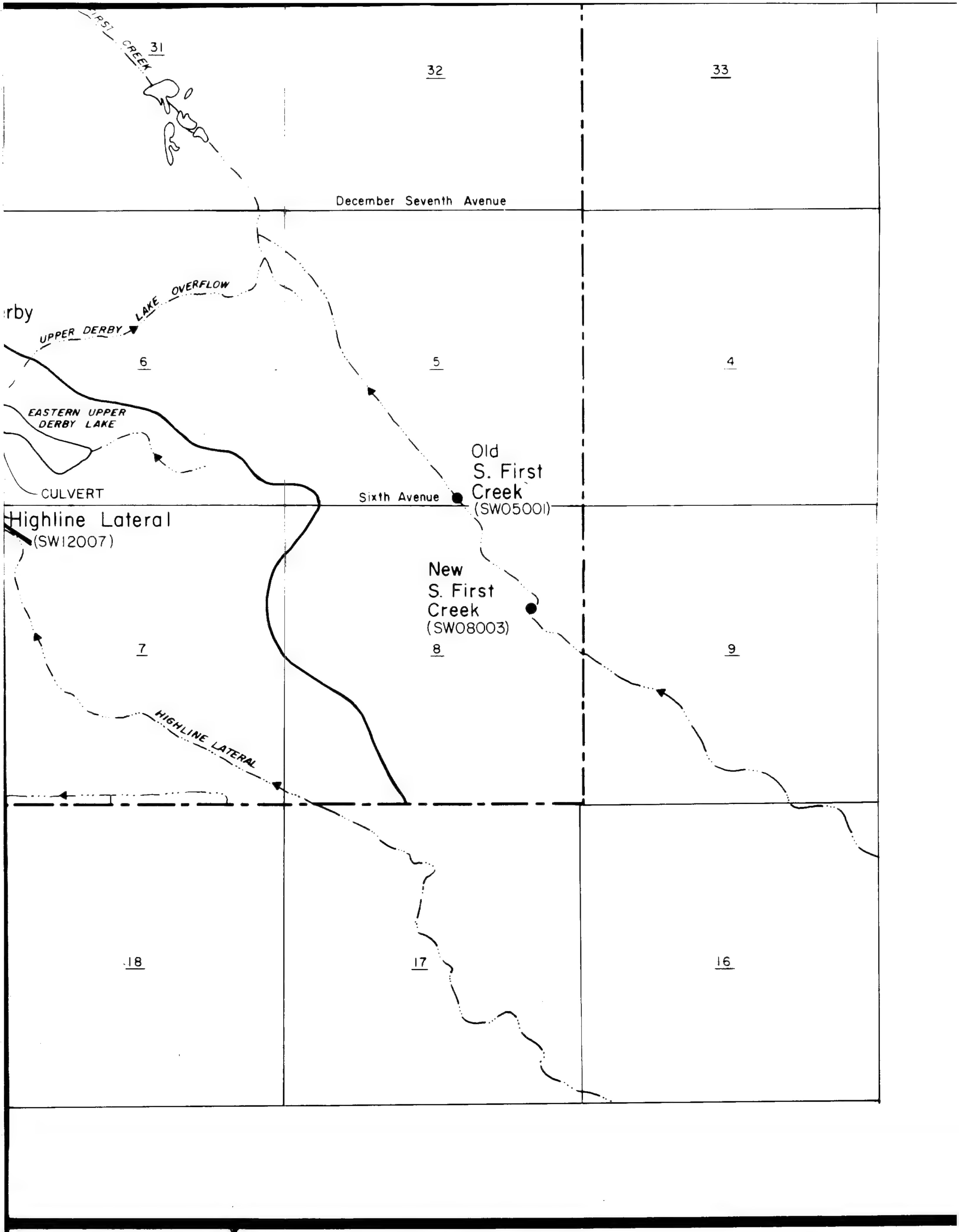
18
17
16
SECOND CREEK
19
"F" Street
20
21
Ninth Avenue
30
29
28
Eighth Avenue
FIRST CREEK
31
32
33


16
21
28
33
Legend
20
Section Number
Lake, Pond or Basin
Stream or Ditch with Flow Direction
Abandoned Stream or Ditch
Water Level Recording Station Locations (SW37001) Corresponding Sampling Identification Number
Staff Gage Locations
Flow Meter Locations
Arsenal Boundary
Drainage Basin Boundary

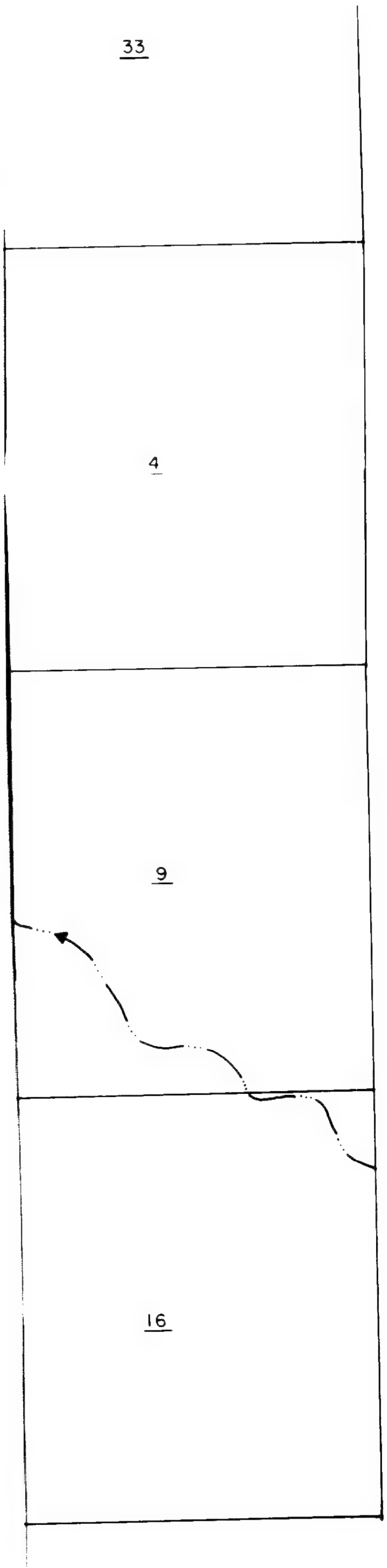


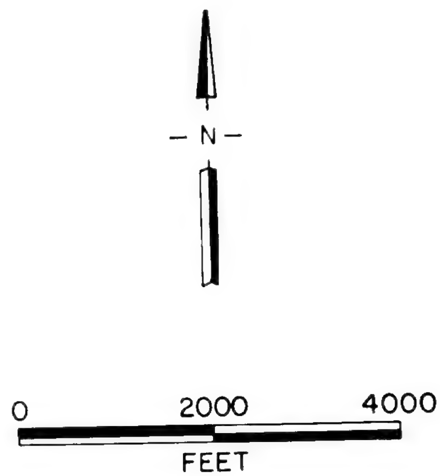
32
33
34
Ladora La
(SW02003)
5
4
3
MOTOR
POOL
RAIL
CLASSIFICATION
YARD
8
9
10
17
16
15


34
35
SAND CREEK
CAUSTIC WASTE BASIN
BASIN A
FIRST CREEK
Basin A
(SW36001)
dora Lake
02003)
SOUTH PLANTS
Upper Derby Lake
(SW01004)
UPPER DERBY
3
SSIFICATION
LAKE MARY
Lake Mary
(SW02004)
LADORA LAKE
2
S. Plants Ditch
(SW01003)
1
6
UPPER DERBY LAKE
EASTERN UPPER DERBY LAKE
Ladora Weir
(SW02001)
LOWER DERBY LAKE
CULVERT
Lower Derby Lake
(SW01005)
N. Uvalda
(SW01001)
Highline Latera
(SW12007)
ROD and GUN CLUB POND
SAND CREEK LATERAL
Havana Pond (SW11003)
11
HAVANA POND
10
12
UVALDA INTERCEPTOR
7
Havana Interceptor
(SW11002)
HAVANA INTERCEPTOR
PEORIA INTERCEPTOR
S. Uvalda
(SW12005)
Peoria Interceptor
(SW11001)
15
14
13
18



FIRST CREEK
31
32
33
December Seventh Avenue
rby
UPPER DERBY LAKE OVERFLOW
6
5
4
EASTERN UPPER DERBY LAKE
CULVERT
Old S. First Creek (SW05001)
Sixth Avenue
Highline Lateral (SW12007)
New S. First Creek (SW08003)
7
8
9
HIGHLINE LATERAL
18
17
16





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Rocky Mountain Arsenal
Commerce City, Colorado

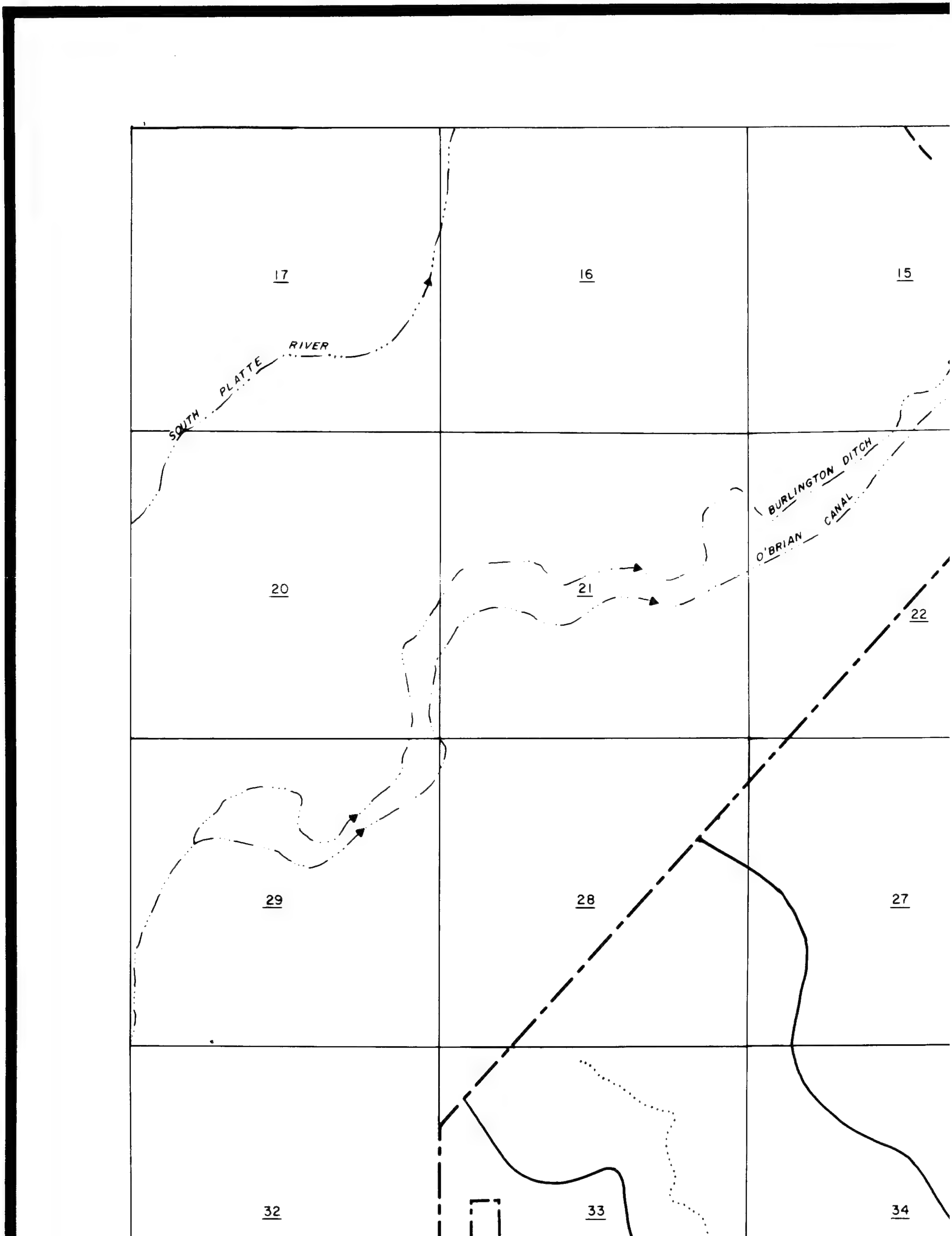
Prepared by :

R.L. Stollar & Associates, Inc.
Harding Lawson Associates

Plate 1.3-1

Surface-Water Quantity Monitoring Station Locations

CMP SW FY89



17
16
15
SOUTH PLATTE RIVER
BURLINGTON DITCH
O'BRIAN CANAL
20
21
22
29
28
27
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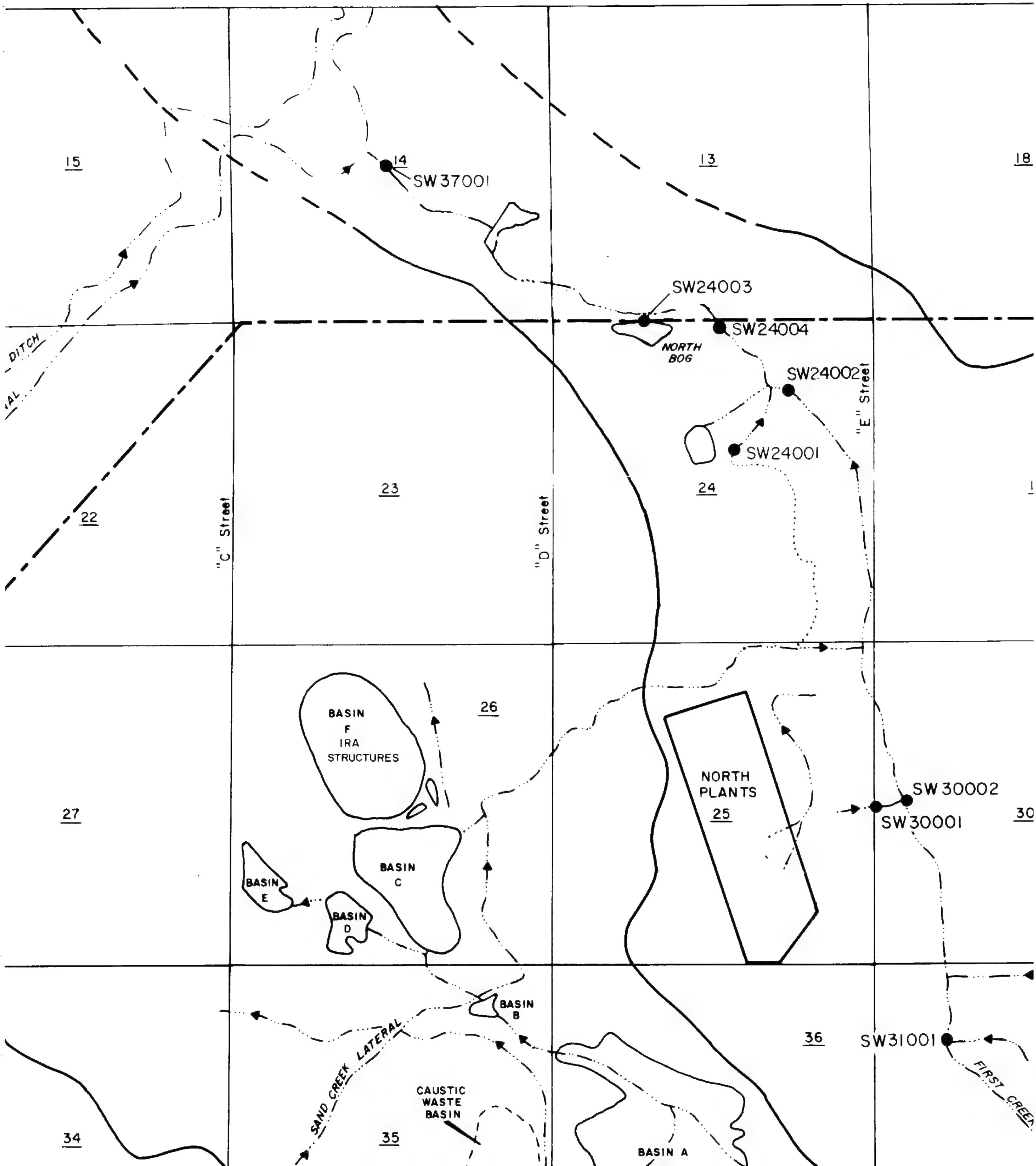
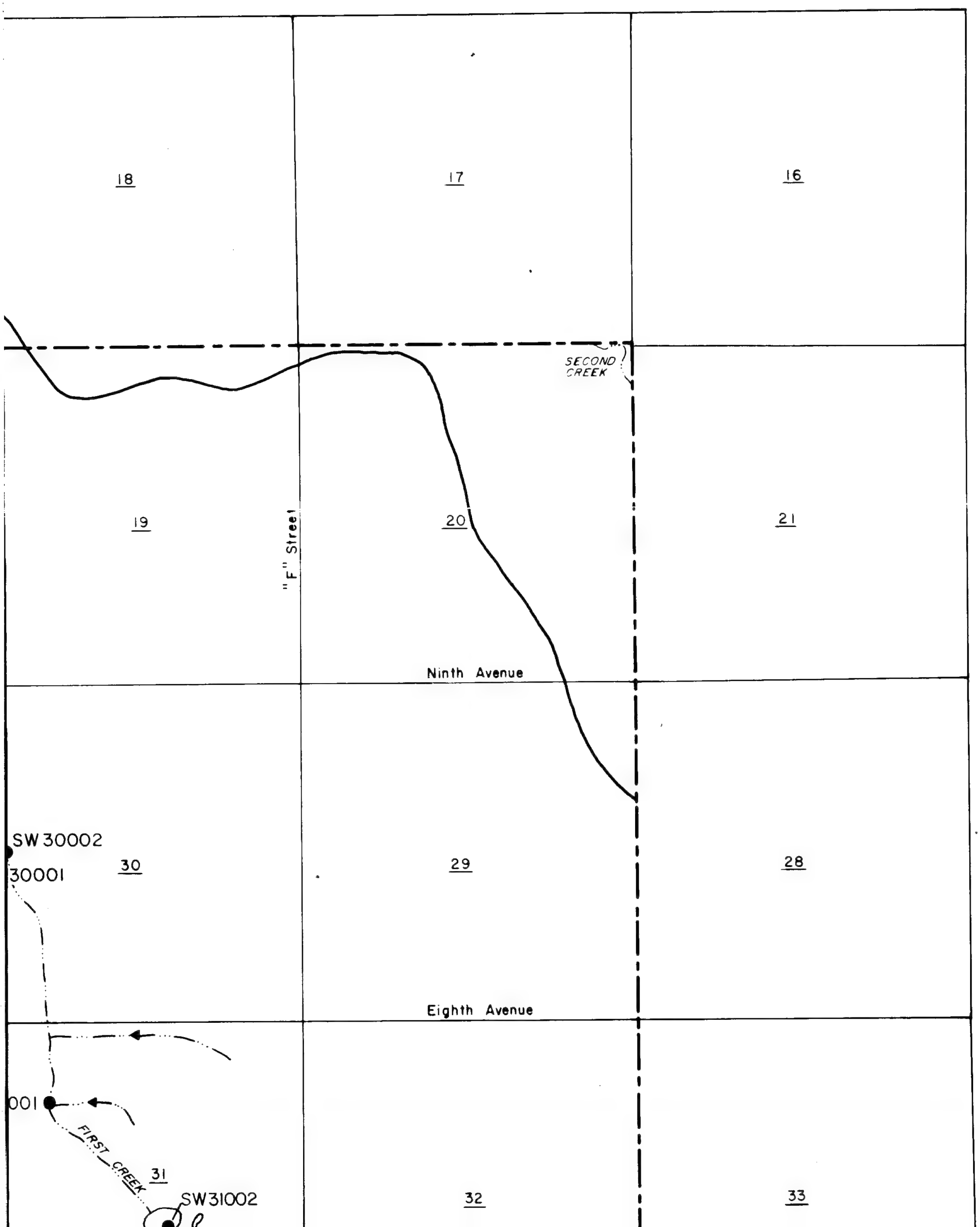
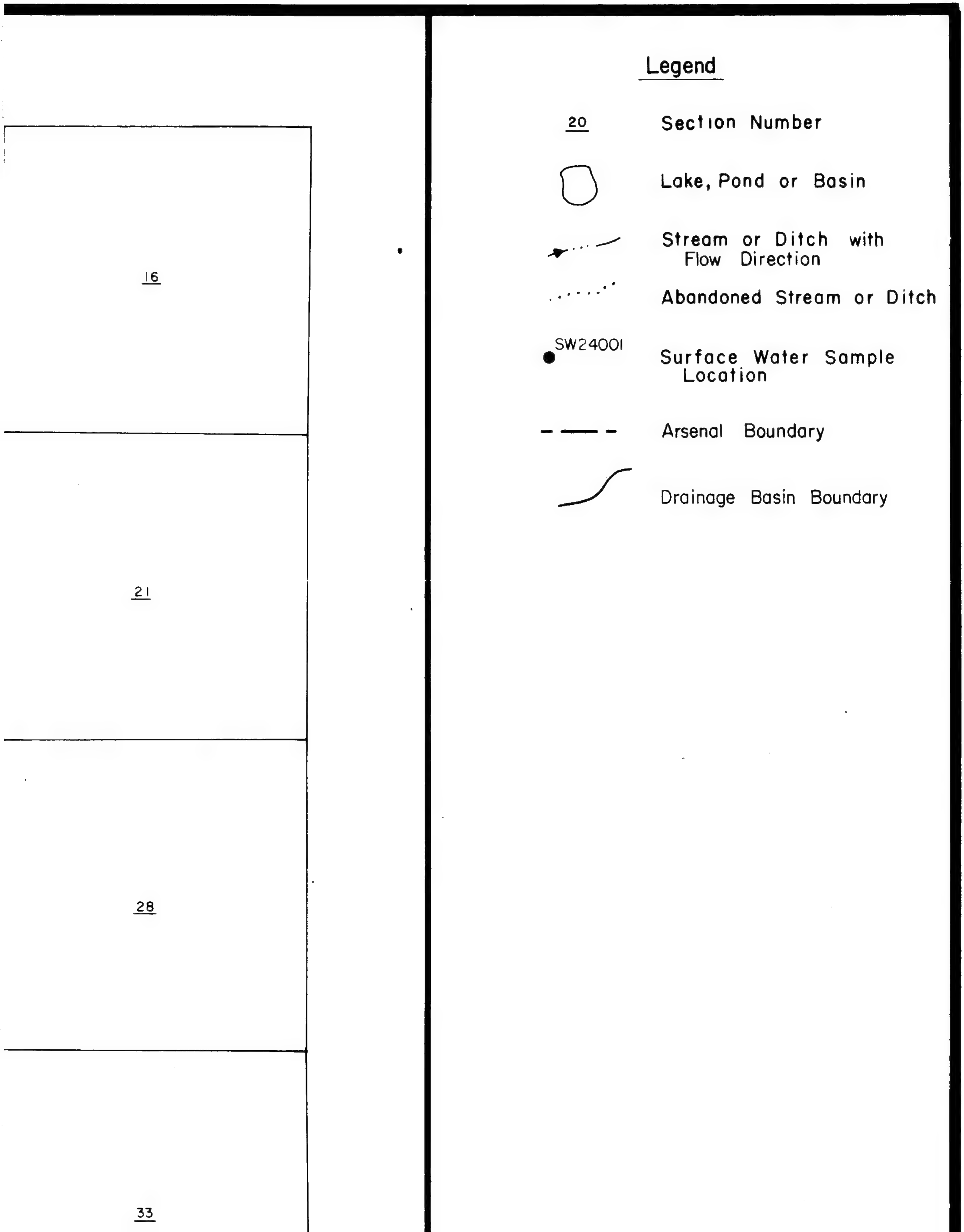
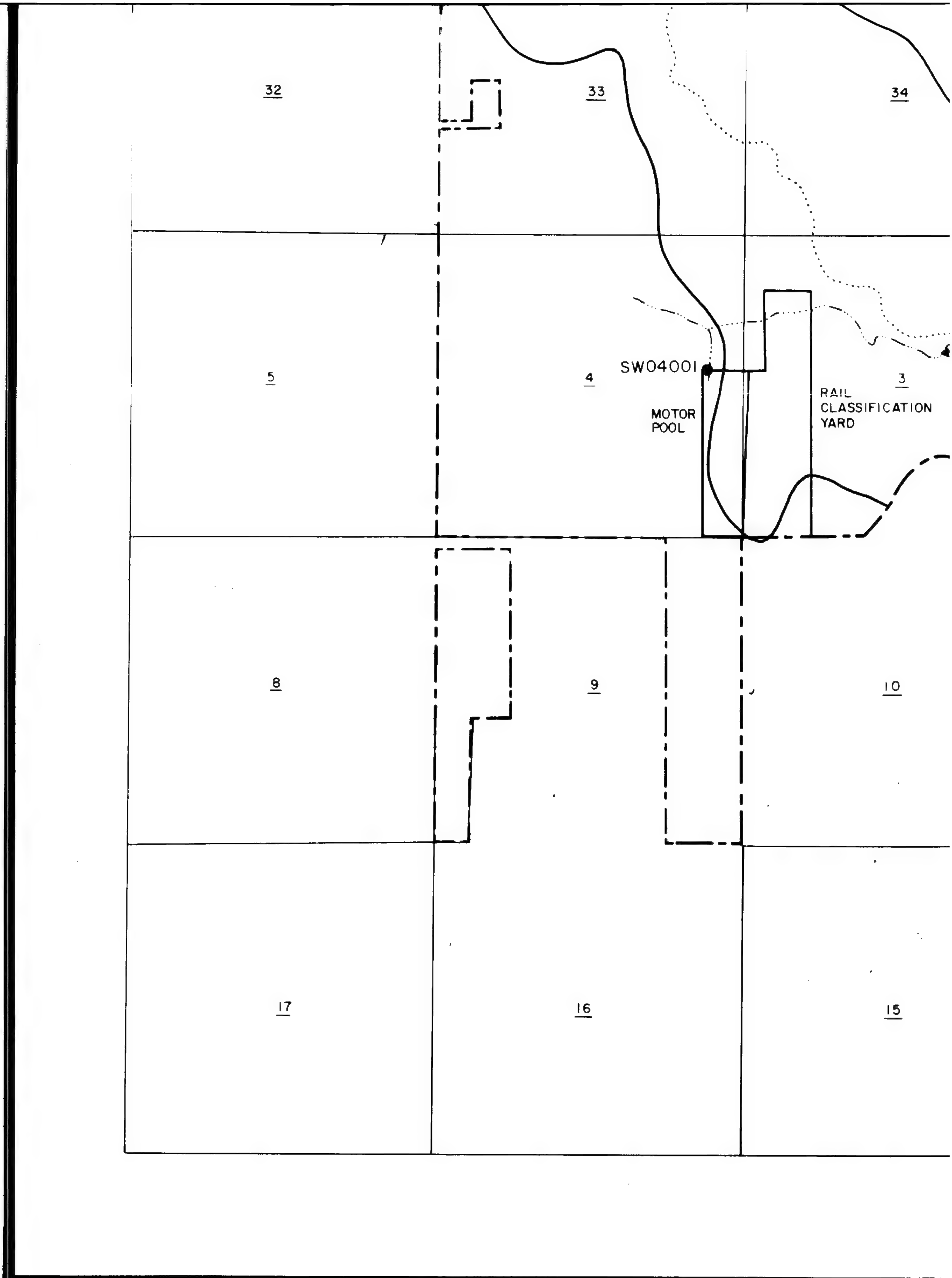
33
34

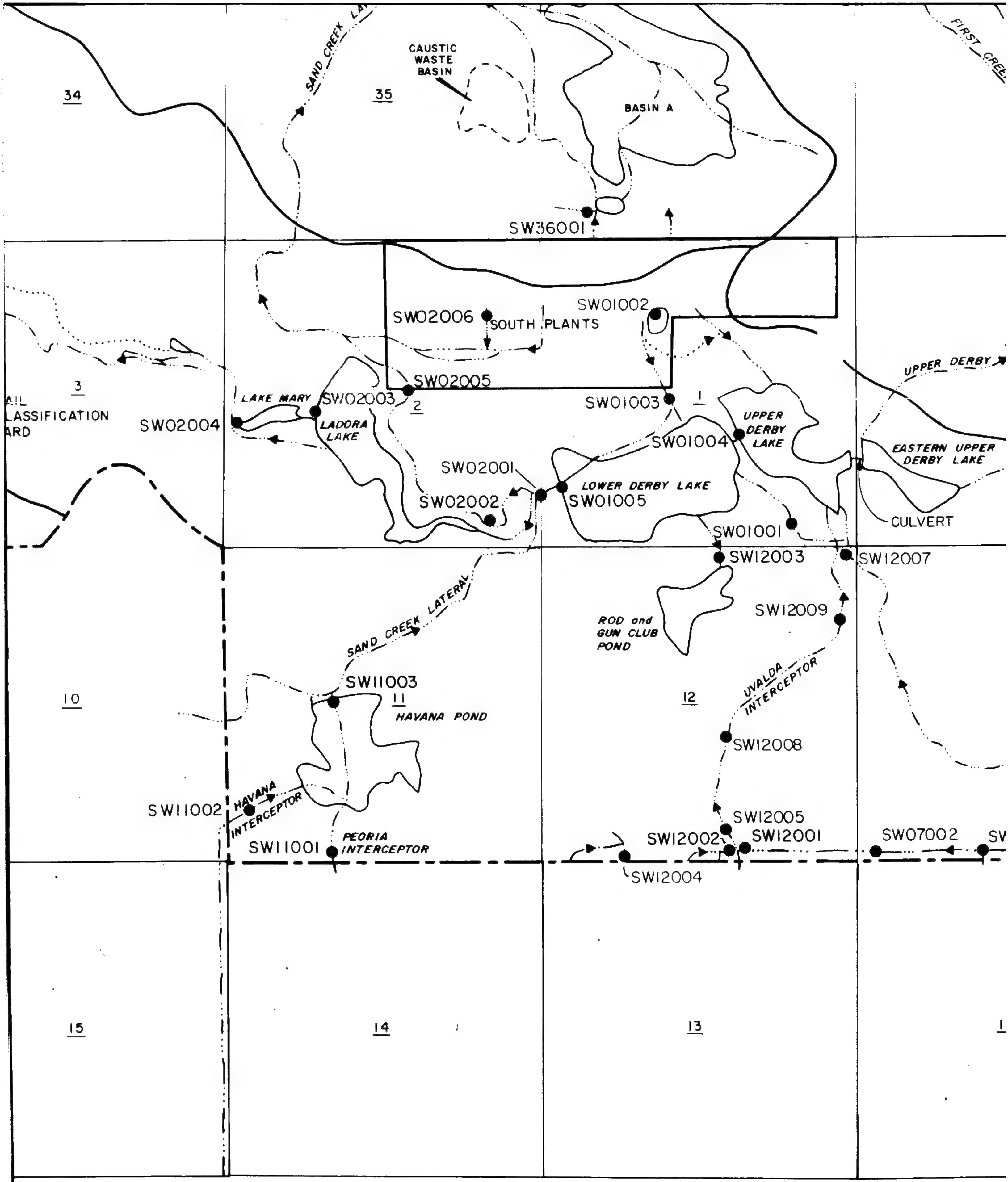


15
14
SW37001
13
18
SW24003
SW24004
NORTH BOG
SW24002
"E" Street
SW24001
DITCH
22
23
24
"C" Street
"D" Street
BASIN F IRA STRUCTURES
26
27
NORTH PLANTS
25
SW30002
SW30001
30
BASIN E
BASIN C
BASIN D
BASIN B
36
SW31001
SAND CREEK LATERAL
FIRST CREEK
CAUSTIC WASTE BASIN
34
35
BASIN A

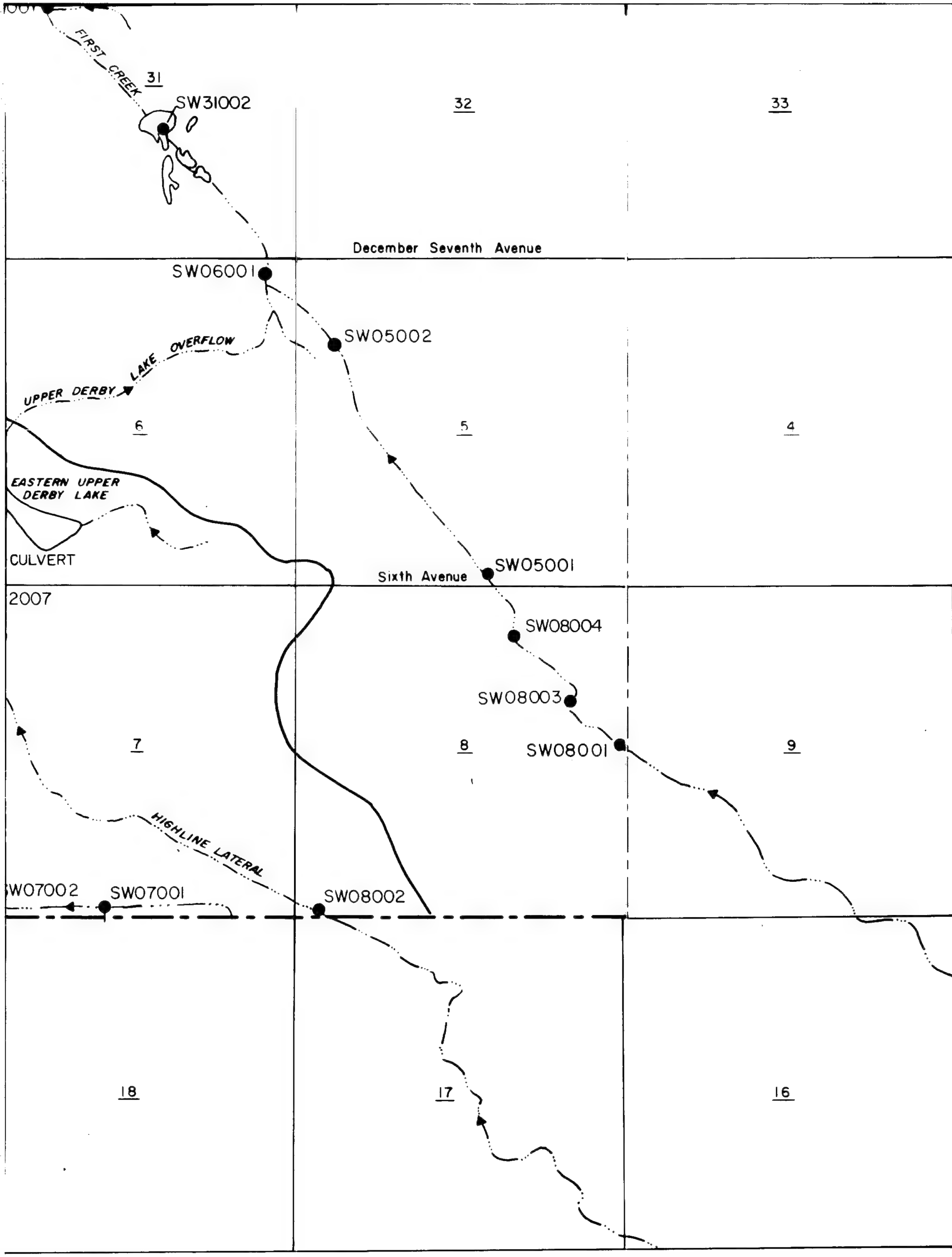

18
17
16
SECOND CREEK
19
"F" Street
20
21
Ninth Avenue
SW 30002
30001
30
29
28
Eighth Avenue
001
FIRST CREEK
31
SW31002
32
33

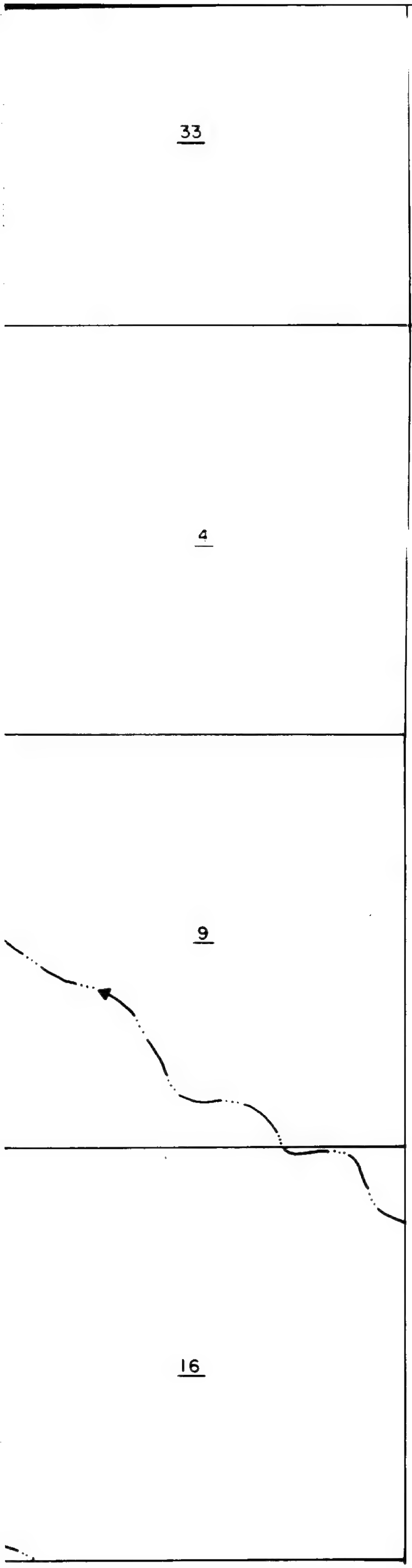

16
21
28
33
Legend
20
Section Number
Lake, Pond or Basin
Stream or Ditch with Flow Direction
Abandoned Stream or Ditch
SW24001
Surface Water Sample Location
Arsenal Boundary
Drainage Basin Boundary

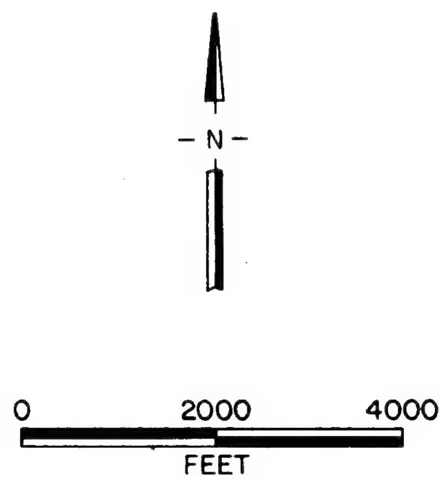

32
33
34
5
4
3
SW04001
MOTOR POOL
RAIL CLASSIFICATION YARD
8
9
10
17
16
15



SAND CREEK LA
CAUSTIC
WASTE
BASIN
BASIN A
FIRST CREE
34
35
SW36001
SW02006
SOUTH PLANTS
SW01002
3
AIL
LASSIFICATION
ARD
SW02004
LAKE MARY
SW02003
LADORA
LAKE
2
SW02005
SW01003
1
UPPER DERBY
UPPER
DERBY
LAKE
EASTERN UPPER
DERBY LAKE
SW01004
SW02001
SW02002
LOWER DERBY LAKE
SW01005
SW01001
CULVERT
SW12003
SW12007
ROD and
GUN CLUB
POND
SW12009
SAND CREEK LATERAL
UVALDA
INTERCEPTOR
10
SW11003
11
HAVANA POND
12
SW12008
SW11002
HAVANA
INTERCEPTOR
SW11001
PEORIA
INTERCEPTOR
SW12005
SW12002
SW12001
SW07002
SW12004
15
14
13


FIRST CREEK
31
SW31002
32
33
December Seventh Avenue
SW06001
SW05002
UPPER DERBY LAKE OVERFLOW
6
5
4
EASTERN UPPER DERBY LAKE
CULVERT
SW05001
Sixth Avenue
2007
SW08004
SW08003
7
8
SW08001
9
HIGHLINE LATERAL
W07002
SW07001
SW08002
18
17
16





Prepared for:

U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

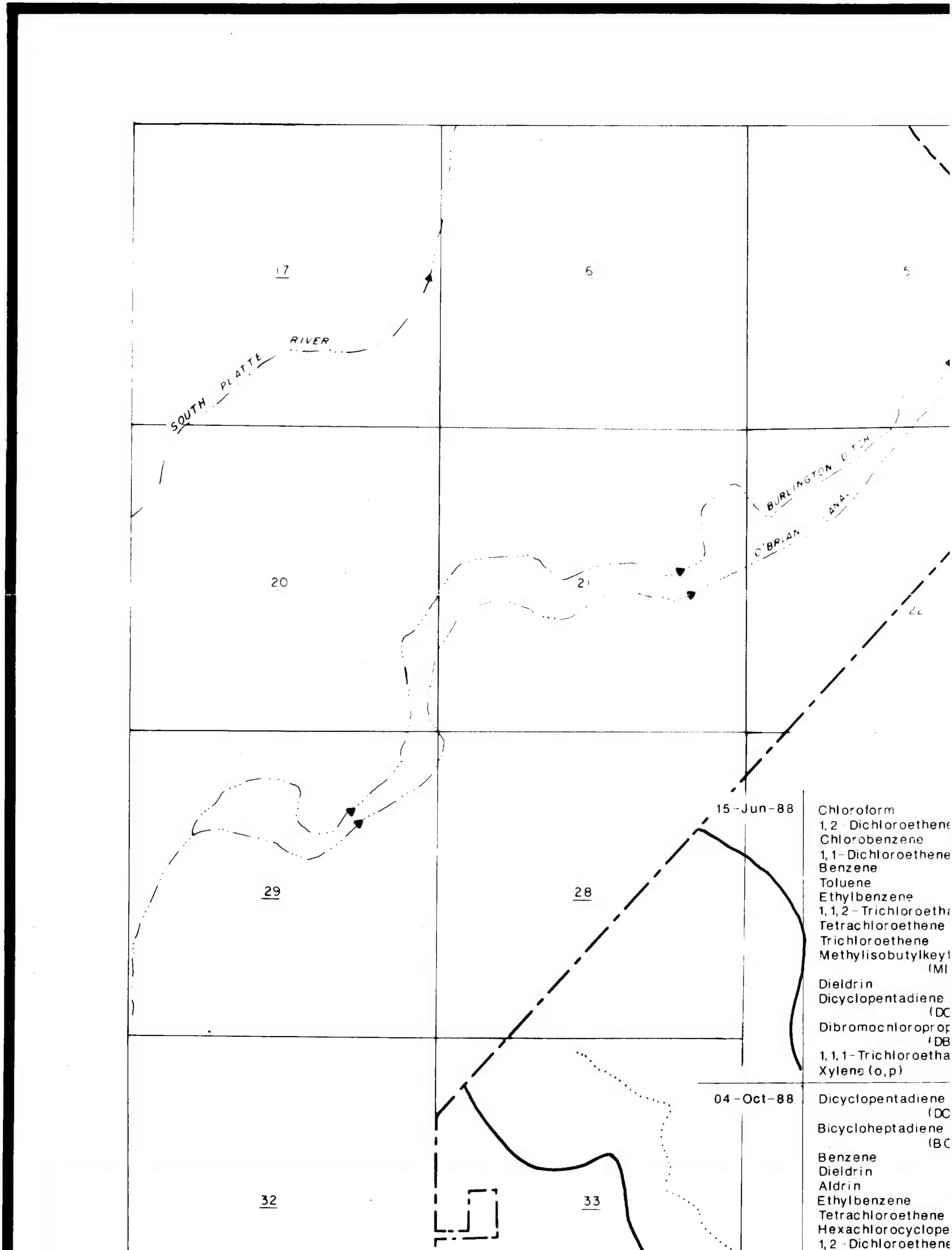
Prepared by:

R.L. Stollar & Associates, Inc.
Harding Lawson Associates

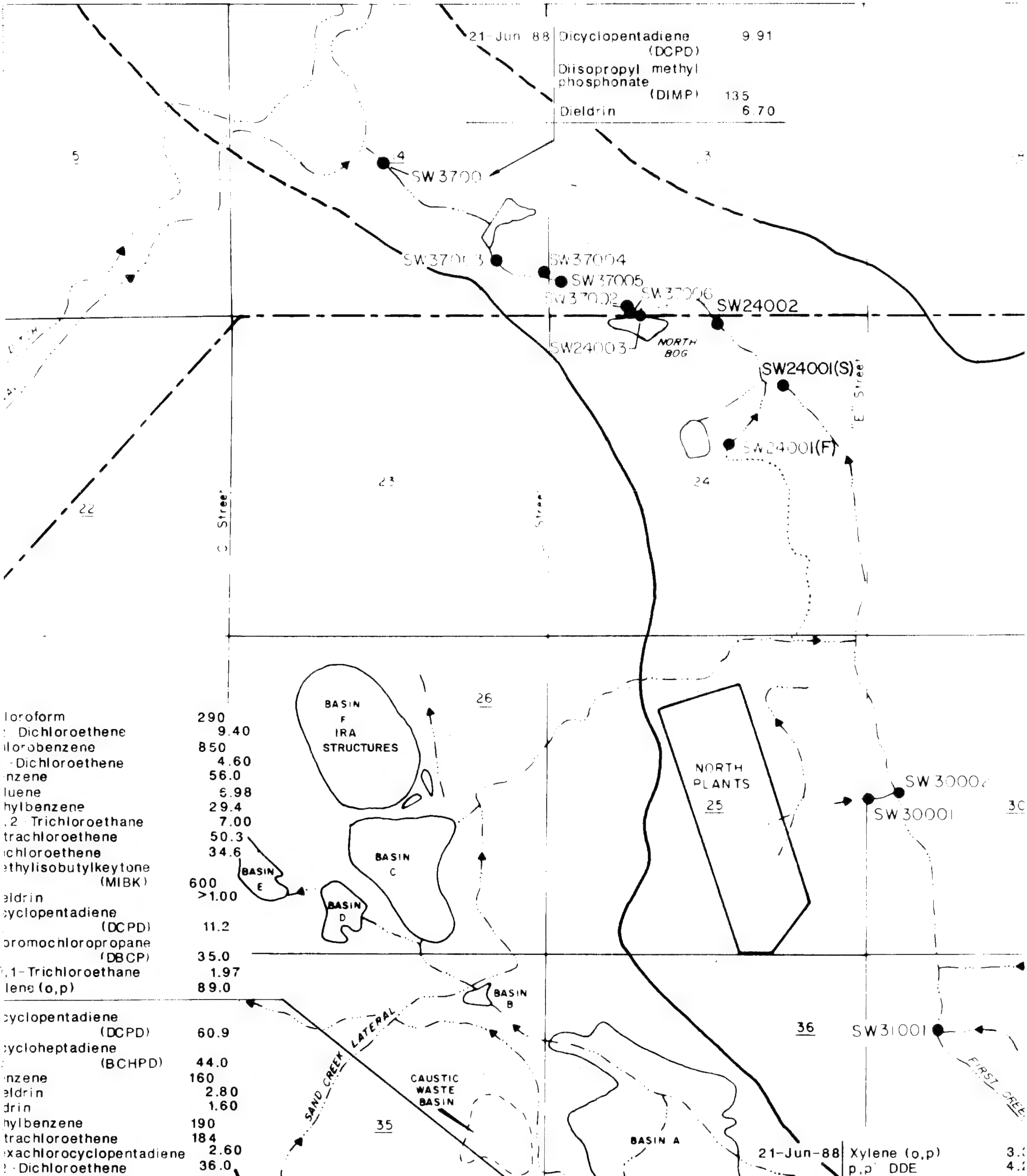
Plate 1.3-2

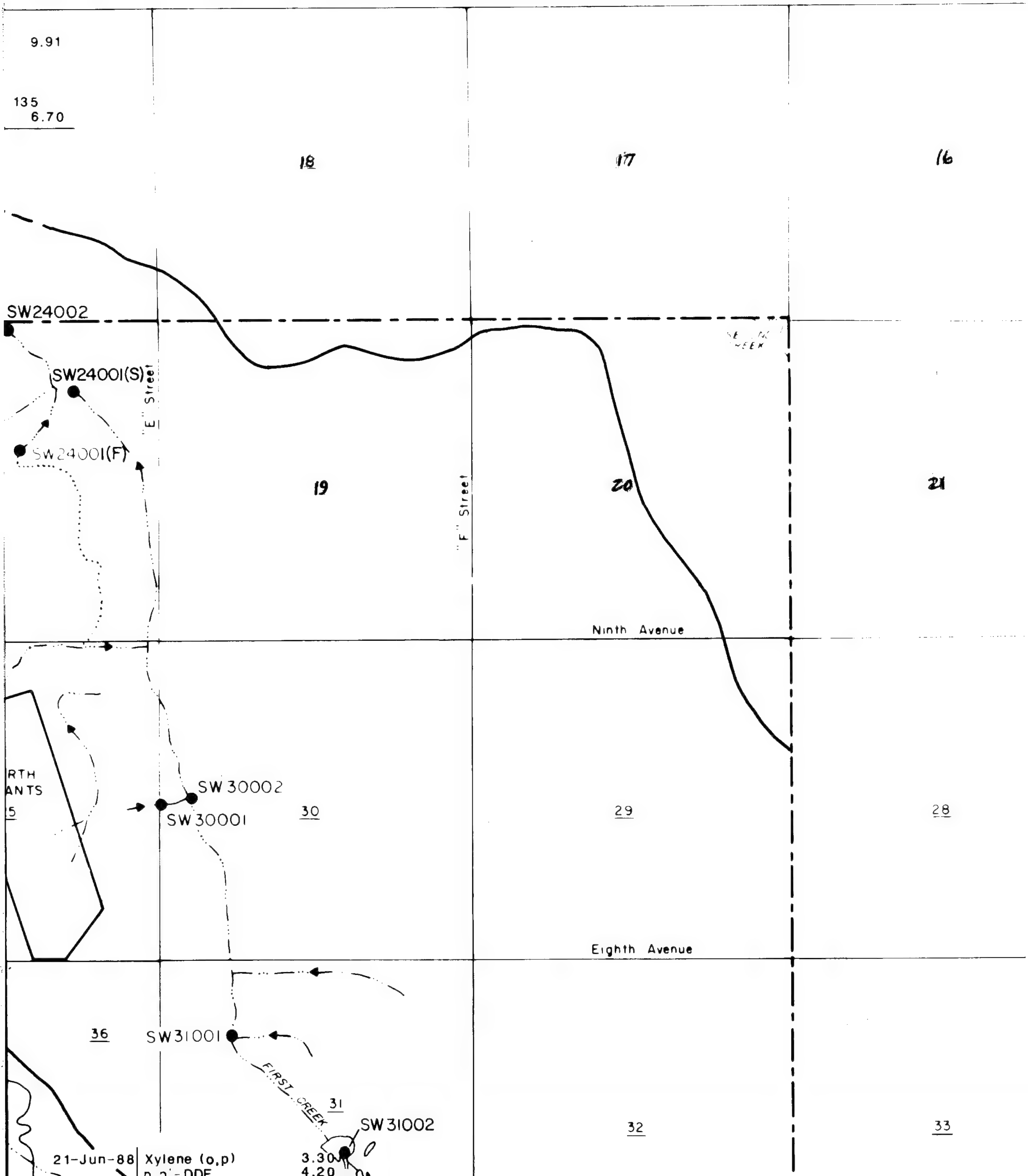
Surface-Water Quality Sampling Locations

CMP SW FY89

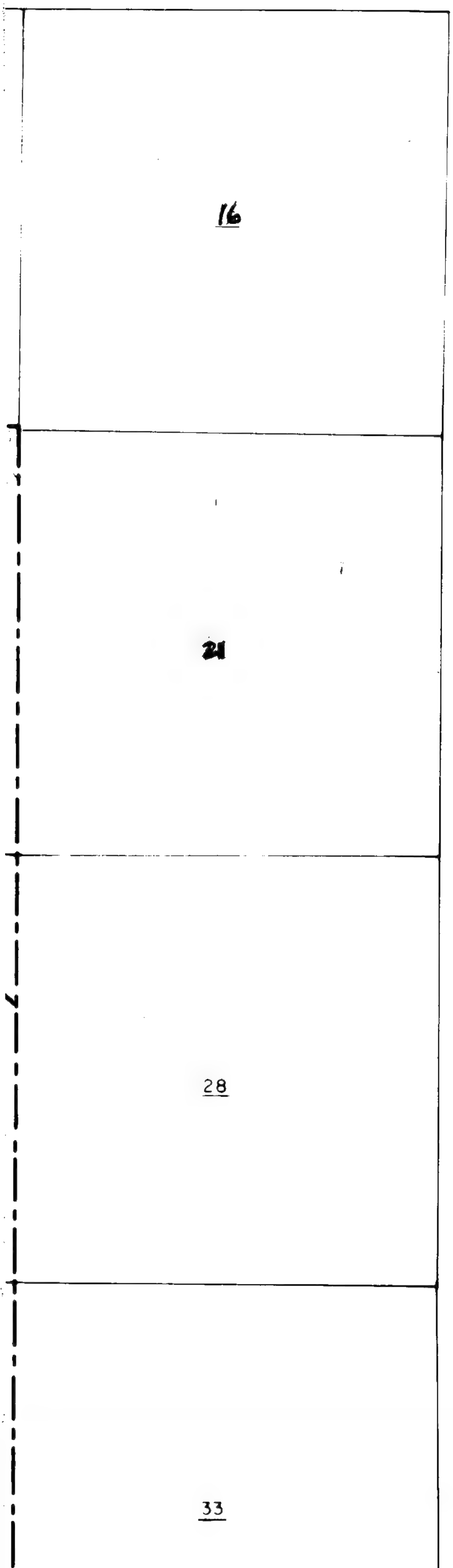


17
6
5
SOUTH PLATTE RIVER
BURLINGTON DITCH
O'BRIAN CANAL
20
21
29
28
32
33
15-Jun-88
Chloroform
1,2-Dichloroethene
Chlorobenzene
1,1-Dichloroethene
Benzene
Toluene
Ethylbenzene
1,1,2-Trichloroetha
Tetrachloroethene
Trichloroethene
Methylisobutylkey
Dieldrin
Dicyclopentadiene
Dibromocnloroprop
1,1,1-Trichloroetha
Xylene (o,p)
04-Oct-88
Dicyclopentadiene
Bicycloheptadiene
Benzene
Dieldrin
Aldrin
Ethylbenzene
Tetrachloroethene
Hexachlorocyclope
1,2-Dichloroethene


21-Jun-88
Dicyclopentadiene (DCPD) 9.91
Diisopropyl methyl phosphonate (DIMP) 135
Dieldrin 6.70
SW3700
SW37003
SW37004
SW37005
SW37002
SW37006
SW24002
SW24003
NORTH BOG
SW24001(S)
SW24001(F)
"E" Street
C Street
Street
5
4
3
22
23
24
25
26
30
35
36
loroform 290
Dichloroethene 9.40
lorobenzene 850
Dichloroethene 4.60
nzene 56.0
luene 6.98
hylbenzene 29.4
,2 Trichloroethane 7.00
trachloroethene 50.3
ichloroethene 34.6
ethylisobutylketone (MIBK) 600
eldrin >1.00
cyclopentadiene (DCPD) 11.2
bromochloropropane (DBCP) 35.0
,1-Trichloroethane 1.97
lene (o,p) 89.0
cyclopentadiene (DCPD) 60.9
cycloheptadiene (BCHPD) 44.0
nzene 160
eldrin 2.80
drin 1.60
hylbenzene 190
trachloroethene 184
xachlorocyclopentadiene 2.60
Dichloroethene 36.0
BASIN F IRA STRUCTURES
BASIN E
BASIN D
BASIN C
BASIN B
BASIN A
NORTH PLANTS
SW30002
SW30001
SW31001
FIRST CREEK
SAND CREEK LATERAL
CAUSTIC WASTE BASIN
21-Jun-88
Xylene (o,p)
p,p' DDE



9.91
135
6.70
18
17
16
SW24002
SW24001(S)
"E" Street
SW24001(F)
19
"F" Street
20
21
Ninth Avenue
RTH
ANTS
5
SW30002
SW30001
30
29
28
Eighth Avenue
36
SW31001
FIRST CREEK
31
SW31002
32
33
21-Jun-88
Xylene (o,p)
3.30
4.20



Legend

20 — Section Number

Lake, Pond or Basin

Stream or Ditch with Flow Direction

Abandoned Stream or Ditch

SW24001 — Surface Water Sample Location

Arsenal Boundary

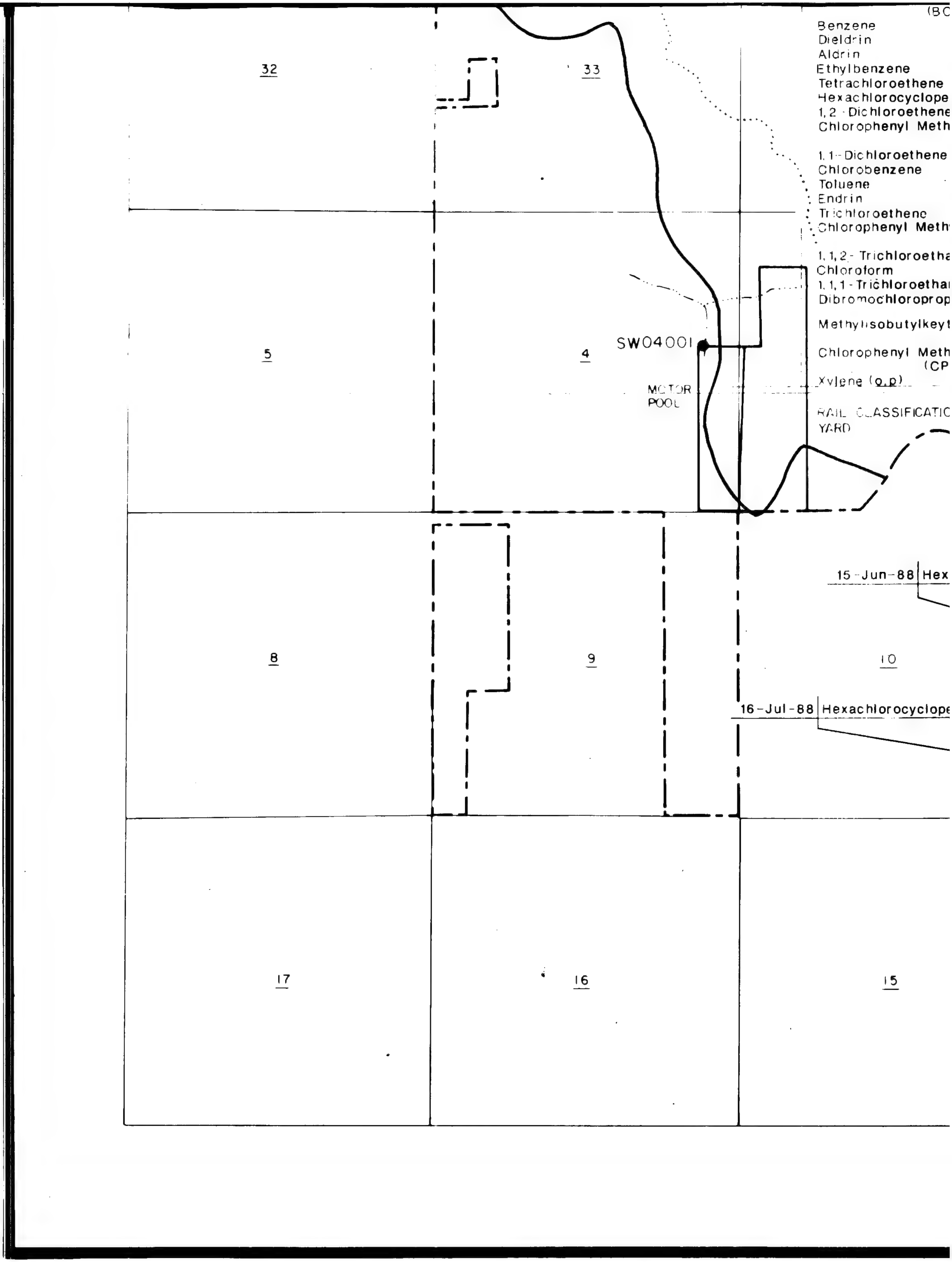
Drainage Basin Boundary

Date	Trace Constituent	Value (µg/l)
07-Jul-88	Chloroform	0.88

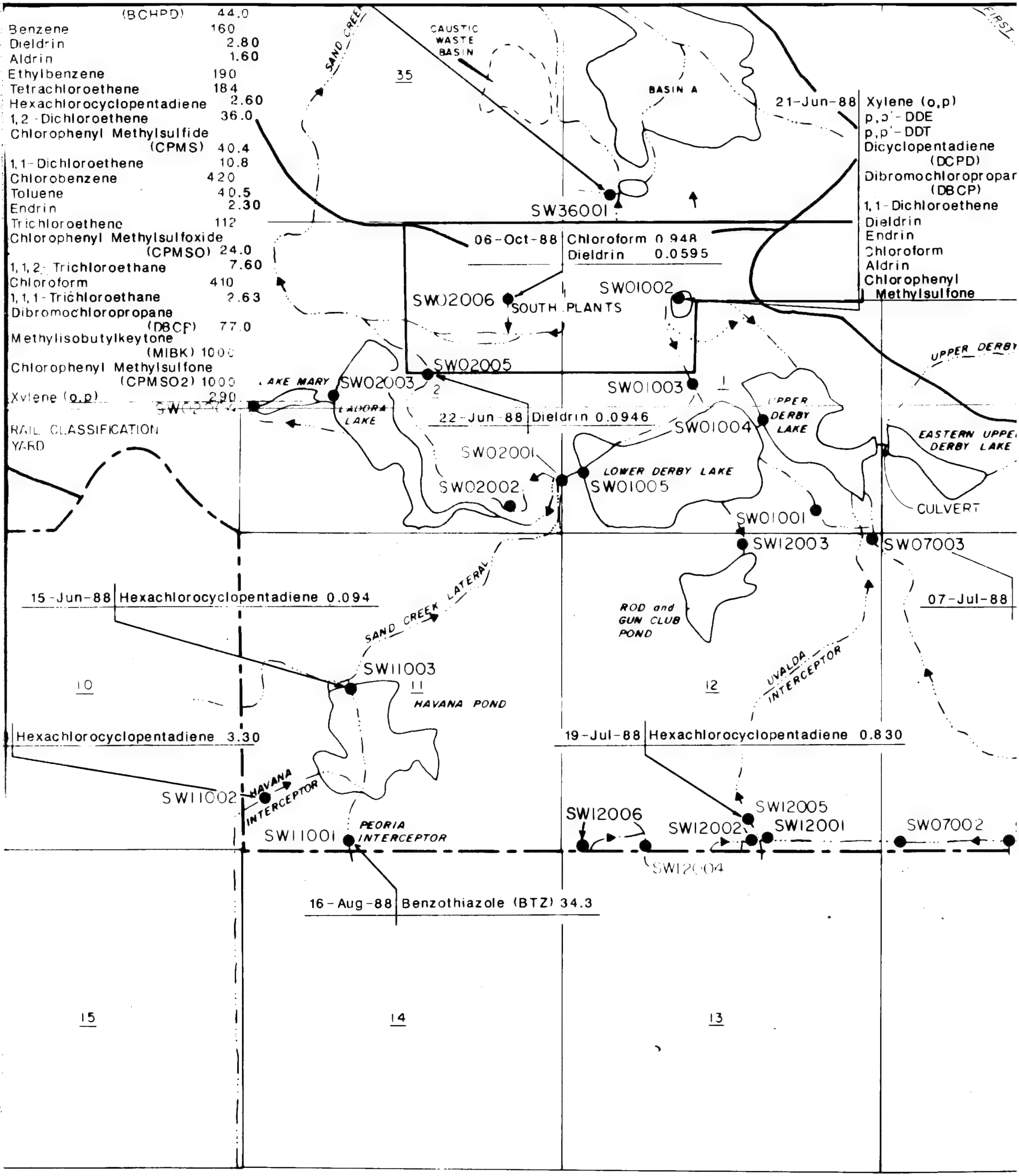
Note :

All data reported in micrograms per liter (ug/l).

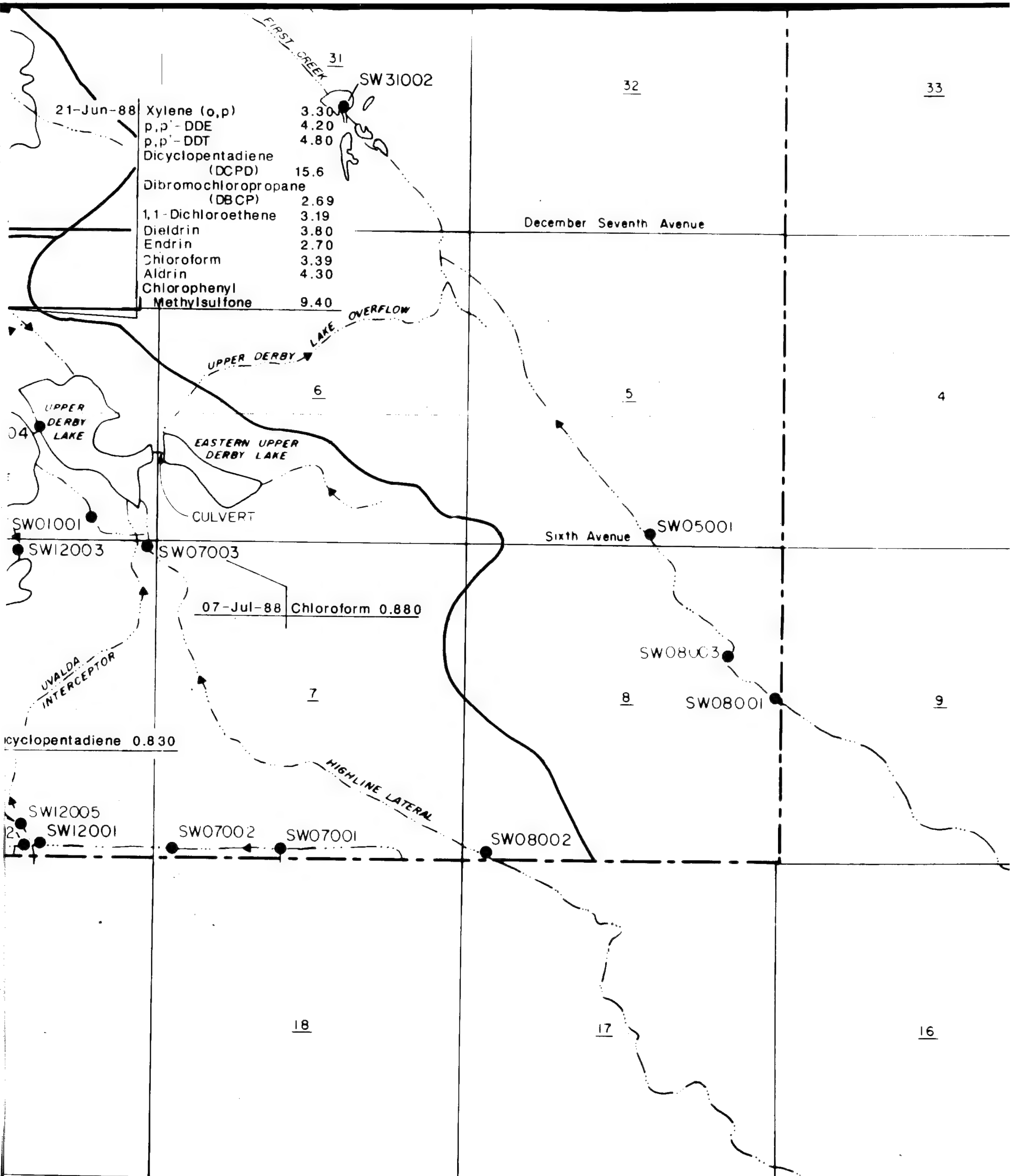
November, 1988 organic analyses for sites SW37002, SW37003, SW37004, SW37005, SW37006 and 37007 are not reported.



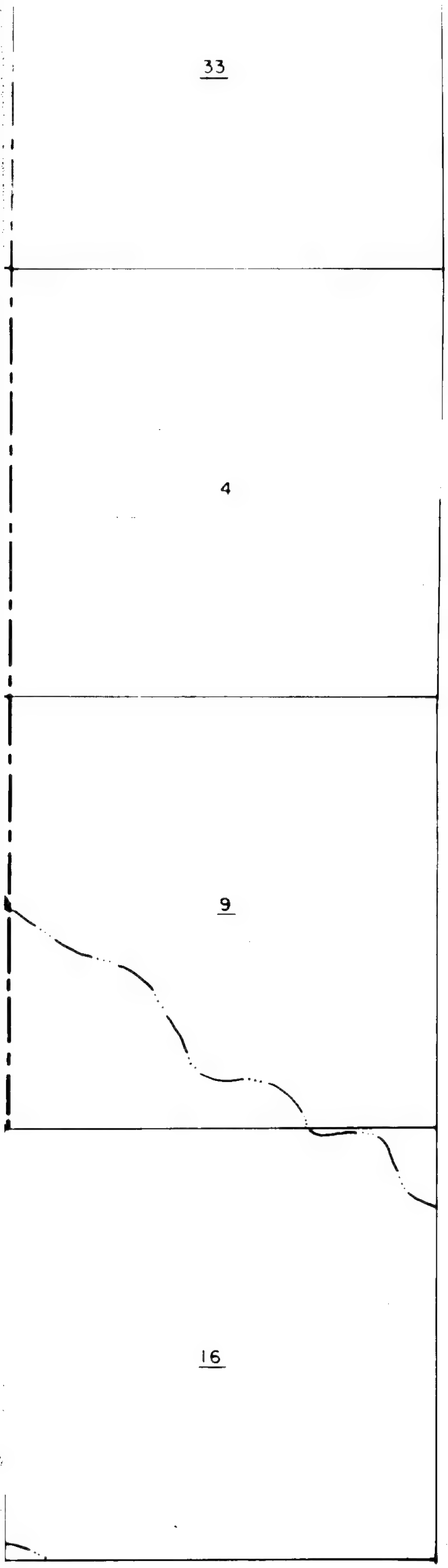
(BC
Benzene
Dieldrin
Aldrin
Ethylbenzene
Tetrachloroethene
Hexachlorocyclope
1, 2 - Dichloroethene
Chlorophenyl Meth
1, 1 - Dichloroethene
Chlorobenzene
Toluene
Endrin
Trichloroethene
Chlorophenyl Meth
1, 1, 2 - Trichloroetha
Chloroform
1, 1, 1 - Trichloroetha
Dibromochloroprop
Methylisobutylkeyt
Chlorophenyl Meth
(CP
Xylene (o,p)
RAIL CLASSIFICATIO
YARD
32
33
5
4
SW04001
MOTOR
POOL
15 - Jun - 88
Hex
8
9
10
16 - Jul - 88
Hexachlorocyclope
17
16
15

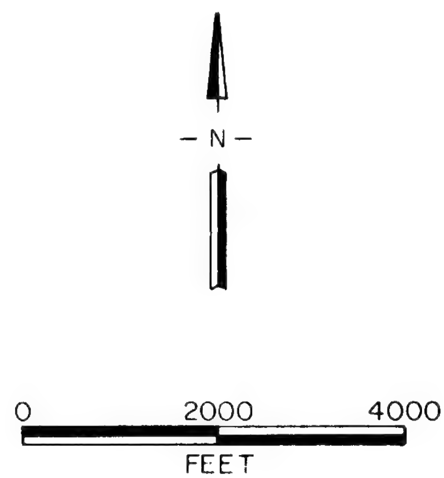


(BCHPD) 44.0
Benzene 160
Dieldrin 2.80
Aldrin 1.60
Ethylbenzene 190
Tetrachloroethene 184
Hexachlorocyclopentadiene 2.60
1,2 -Dichloroethene 36.0
Chlorophenyl Methylsulfide (CPMS) 40.4
1,1-Dichloroethene 10.8
Chlorobenzene 420
Toluene 40.5
Endrin 2.30
Trichloroethene 112
Chlorophenyl Methylsulfoxide (CPMSO) 24.0
1,1,2- Trichloroethane 7.60
Chloroform 410
1,1,1-Trichloroethane 2.63
Dibromochloropropane (DBCP) 77.0
Methylisobutylketone (MIBK) 1000
Chlorophenyl Methylsulfone (CPMSO2) 1000
Xylene (o,p) 290
SAND CREEK
CAUSTIC WASTE BASIN
35
BASIN A
FIRST
21-Jun-88
Xylene (o,p)
p,p'-DDE
p,p'-DDT
Dicyclopentadiene (DCPD)
Dibromochloropropan
(DBCP)
1,1-Dichloroethene
Dieldrin
Endrin
Chloroform
Aldrin
Chlorophenyl Methylsulfone
SW36001
06-Oct-88
Chloroform 0.948
Dieldrin 0.0595
SW02006
SOUTH PLANTS
SW01002
SW02005
LAKE MARY
SW02003
2
SW01003
1
UPPER DERBY
LADORA LAKE
22-Jun-88
Dieldrin 0.0946
UPPER DERBY LAKE
SW01004
RAIL CLASSIFICATION YARD
EASTERN UPPER DERBY LAKE
SW02001
LOWER DERBY LAKE
SW01005
SW02002
CULVERT
SW01001
SW12003
SW07003
15-Jun-88
Hexachlorocyclopentadiene 0.094
SAND CREEK LATERAL
07-Jul-88
ROD and GUN CLUB POND
SW11003
10
11
HAVANA POND
12
UVALDA INTERCEPTOR
Hexachlorocyclopentadiene 3.30
19-Jul-88
Hexachlorocyclopentadiene 0.830
HAVANA INTERCEPTOR
SW11002
SW12005
SW12006
SW12002
SW12001
SW07002
SW11001
PEORIA INTERCEPTOR
SW12004
16-Aug-88
Benzothiazole (BTZ) 34.3
15
14
13



FIRST CREEK
31
32
33
SW31002
21-Jun-88
Xylene (o,p) 3.30
p,p'-DDE 4.20
p,p'-DDT 4.80
Dicyclopentadiene (DCPD) 15.6
Dibromochloropropane (DBCP) 2.69
1,1-Dichloroethene 3.19
Dieldrin 3.80
Endrin 2.70
Chloroform 3.39
Aldrin 4.30
Chlorophenyl Methylsulfone 9.40
December Seventh Avenue
UPPER DERBY LAKE OVERFLOW
6
5
4
UPPER DERBY LAKE
04
EASTERN UPPER DERBY LAKE
CULVERT
SW01001
SW12003
SW07003
Sixth Avenue
SW05001
07-Jul-88 Chloroform 0.880
UVALDA INTERCEPTOR
SW08003
7
8
9
SW08001
icyclopentadiene 0.830
HIGHLINE LATERAL
SW12005
SW12001
SW07002
SW07001
SW08002
18
17
16





Prepared for :

U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Coloradc

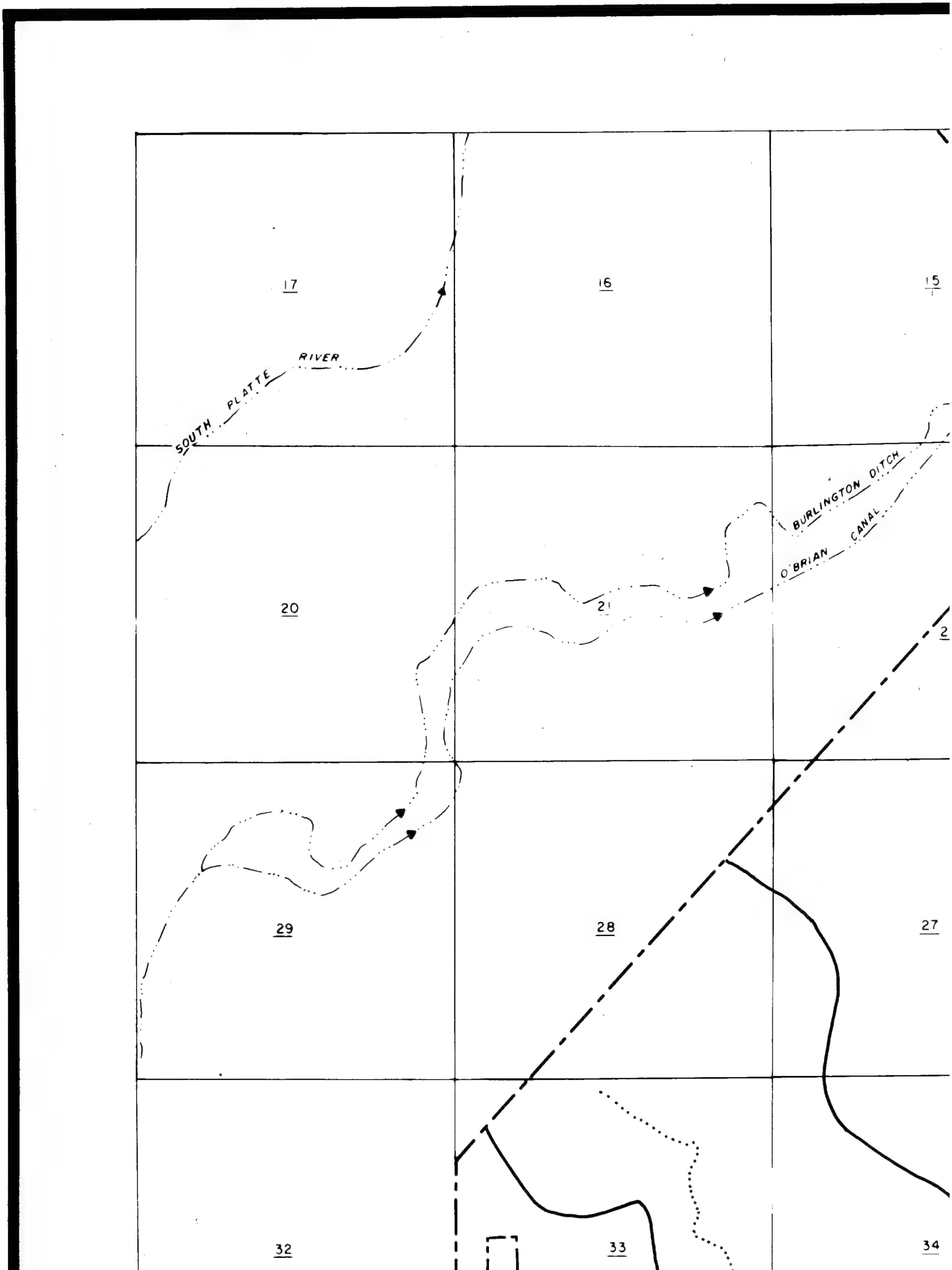
Prepared by :

R.L. Stollar & Associates, Inc.
Harding Lawson Associates

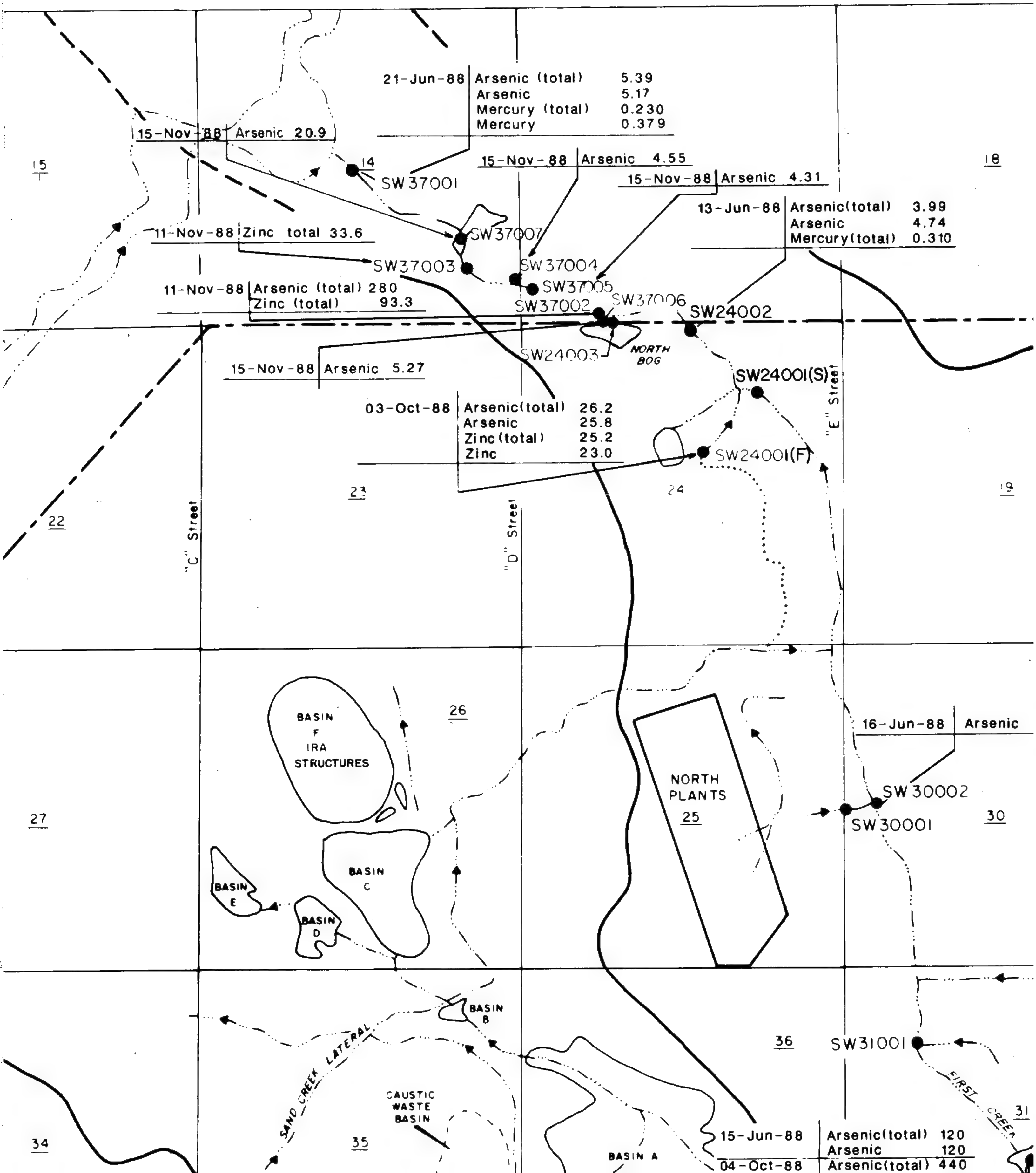
Plate 1.3-3

Occurrence of CMP Surface-Water FY88 Target Organic Compounds

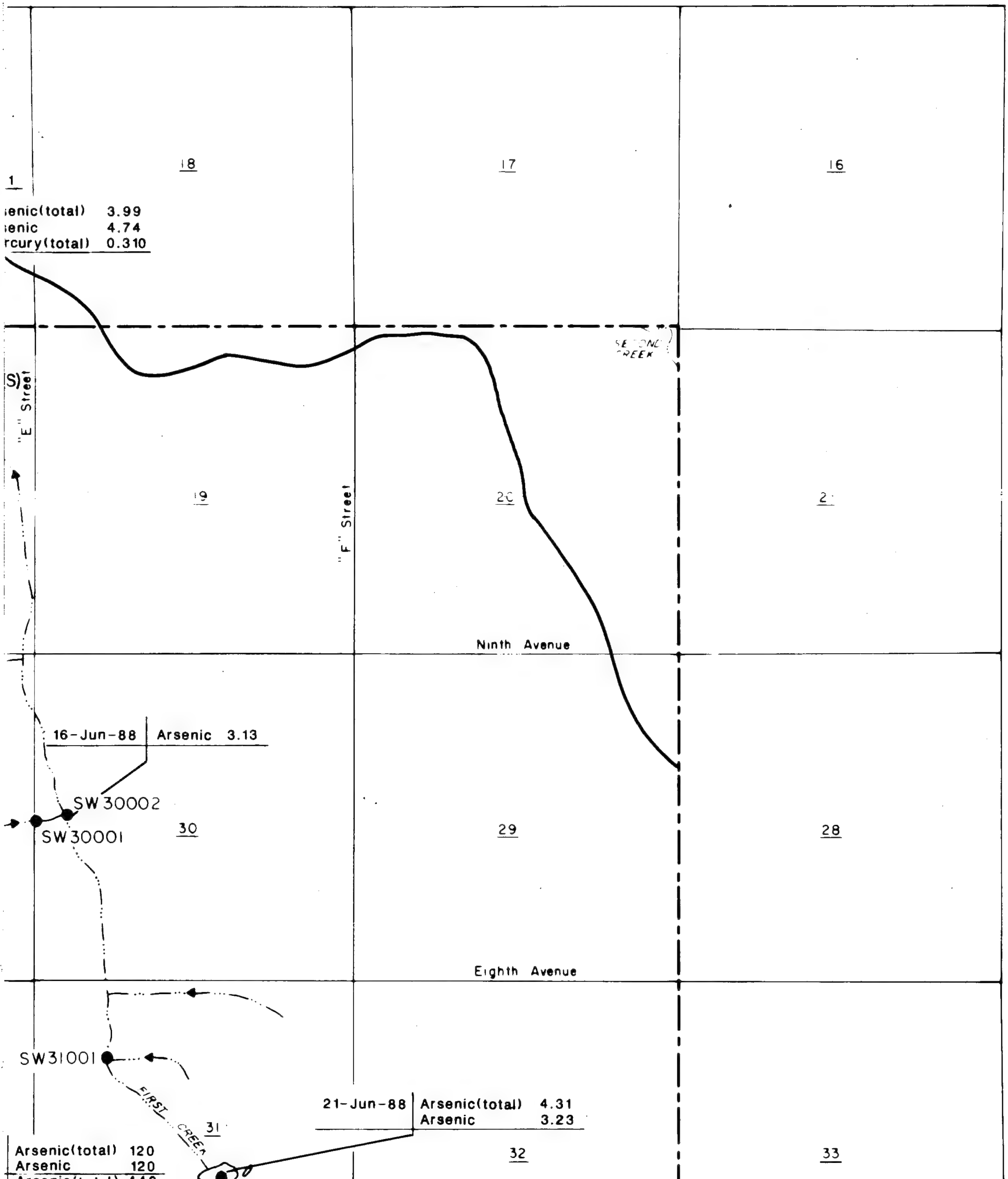
CMPSW FY 89



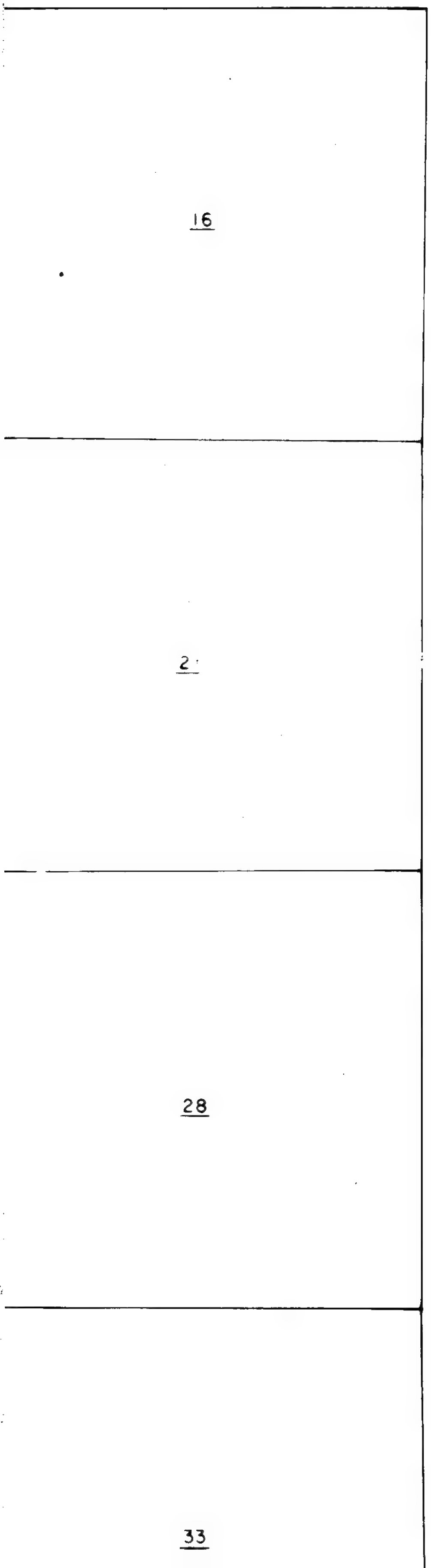
17
16
15
SOUTH PLATTE RIVER
BURLINGTON DITCH
O'BRIAN CANAL
20
21
29
28
27
32
33
34



21-Jun-88 Arsenic (total) 5.39
Arsenic 5.17
Mercury (total) 0.230
Mercury 0.379
15-Nov-88 Arsenic 20.9
15-Nov-88 Arsenic 4.55
15-Nov-88 Arsenic 4.31
13-Jun-88 Arsenic(total) 3.99
Arsenic 4.74
Mercury(total) 0.310
11-Nov-88 Zinc total 33.6
11-Nov-88 Arsenic (total) 280
Zinc (total) 93.3
15-Nov-88 Arsenic 5.27
03-Oct-88 Arsenic(total) 26.2
Arsenic 25.8
Zinc (total) 25.2
Zinc 23.0
16-Jun-88 Arsenic
15-Jun-88 Arsenic(total) 120
Arsenic 120
04-Oct-88 Arsenic(total) 440
SW37001
SW37007
SW37003
SW37004
SW37005
SW37002
SW37006
SW24002
SW24003
SW24001(S)
SW24001(F)
SW30002
SW30001
SW31001
NORTH BOG
"C" Street
"D" Street
"E" Street
BASIN F IRA STRUCTURES
BASIN E
BASIN D
BASIN C
BASIN B
BASIN A
NORTH PLANTS
CAUSTIC WASTE BASIN
SAND CREEK LATERAL
FIRST CREEK
14
15
18
19
22
23
24
25
26
27
30
31
34
35
36



18
17
16
1
senic(total) 3.99
senic 4.74
rcury(total) 0.310
SECOND CREEK
(S)
"E" Street
19
"F" Street
20
21
Ninth Avenue
16-Jun-88
Arsenic 3.13
SW30002
SW30001
30
29
28
Eighth Avenue
SW31001
FIRST CREEK
21-Jun-88
Arsenic(total) 4.31
Arsenic 3.23
31
Arsenic(total) 120
Arsenic 120
32
33



Legend

20 Section Number

Lake, Pond or Basin

Stream or Ditch with Flow Direction

Abandoned Stream or Ditch

SW24001 Surface Water Sample Location

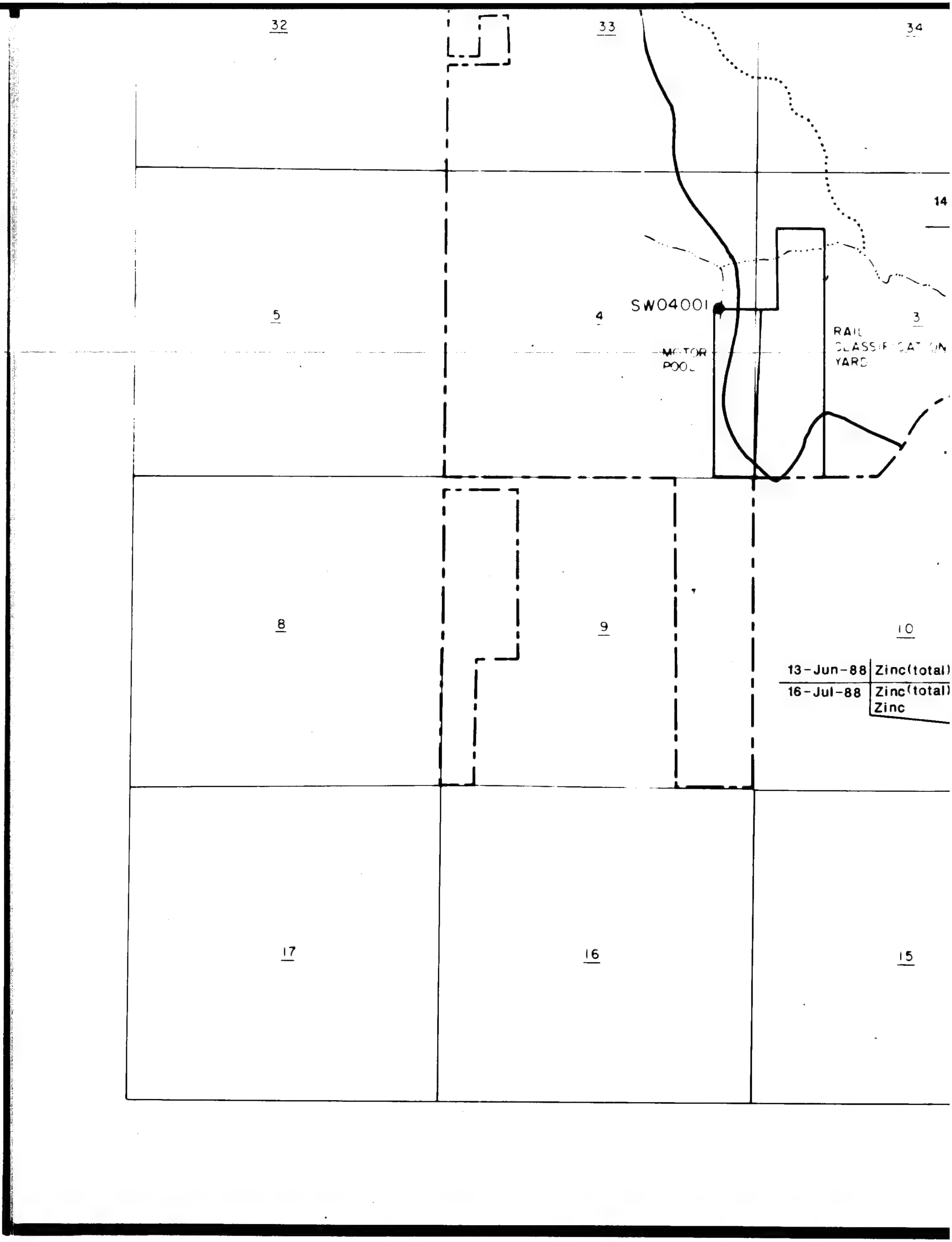
Arsenal Boundary

Drainage Basin Boundary

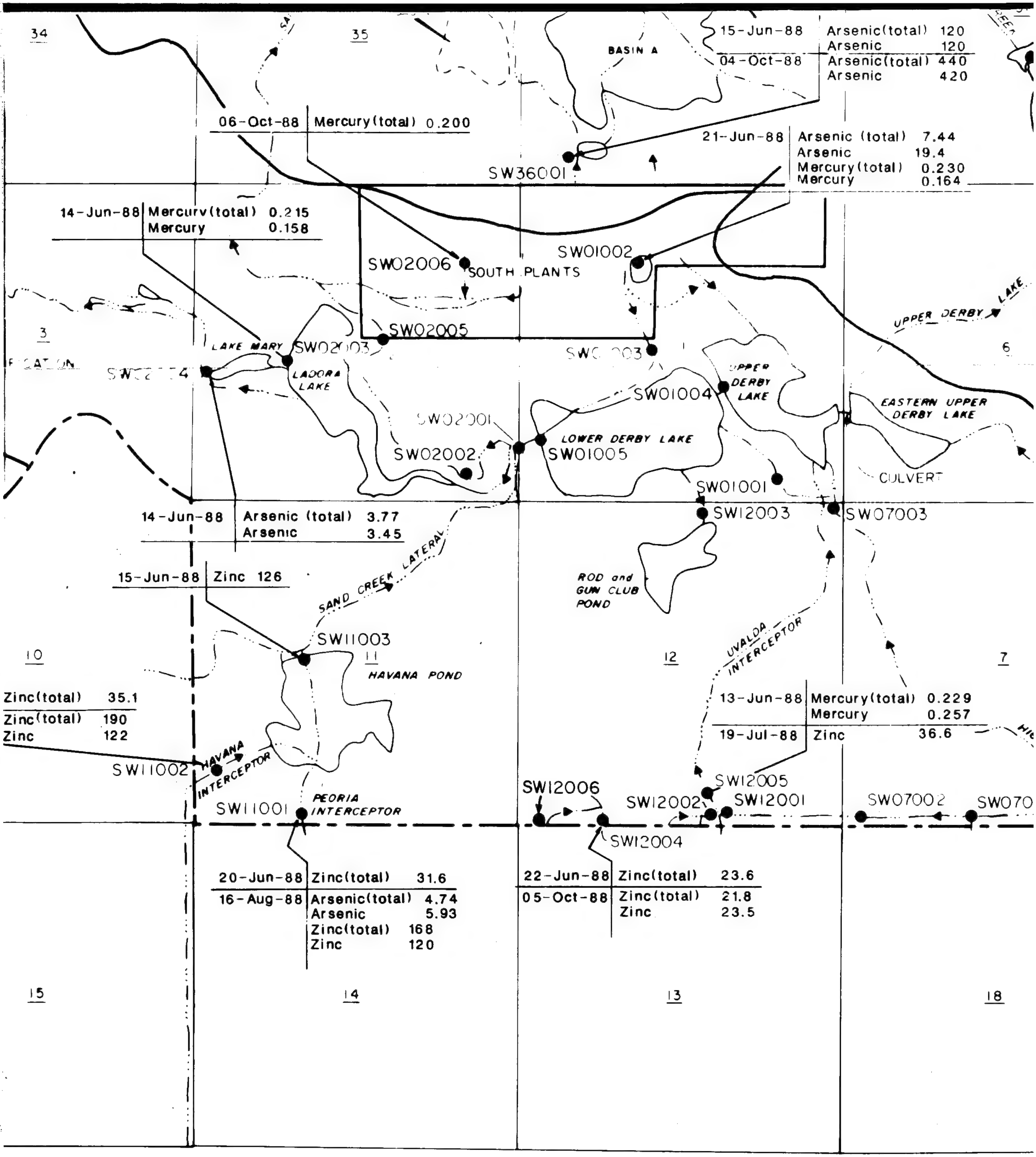
Date	Trace Constituent	Value (µg/l)
03-Oct-88	Arsenic (total)	26.2

Note :

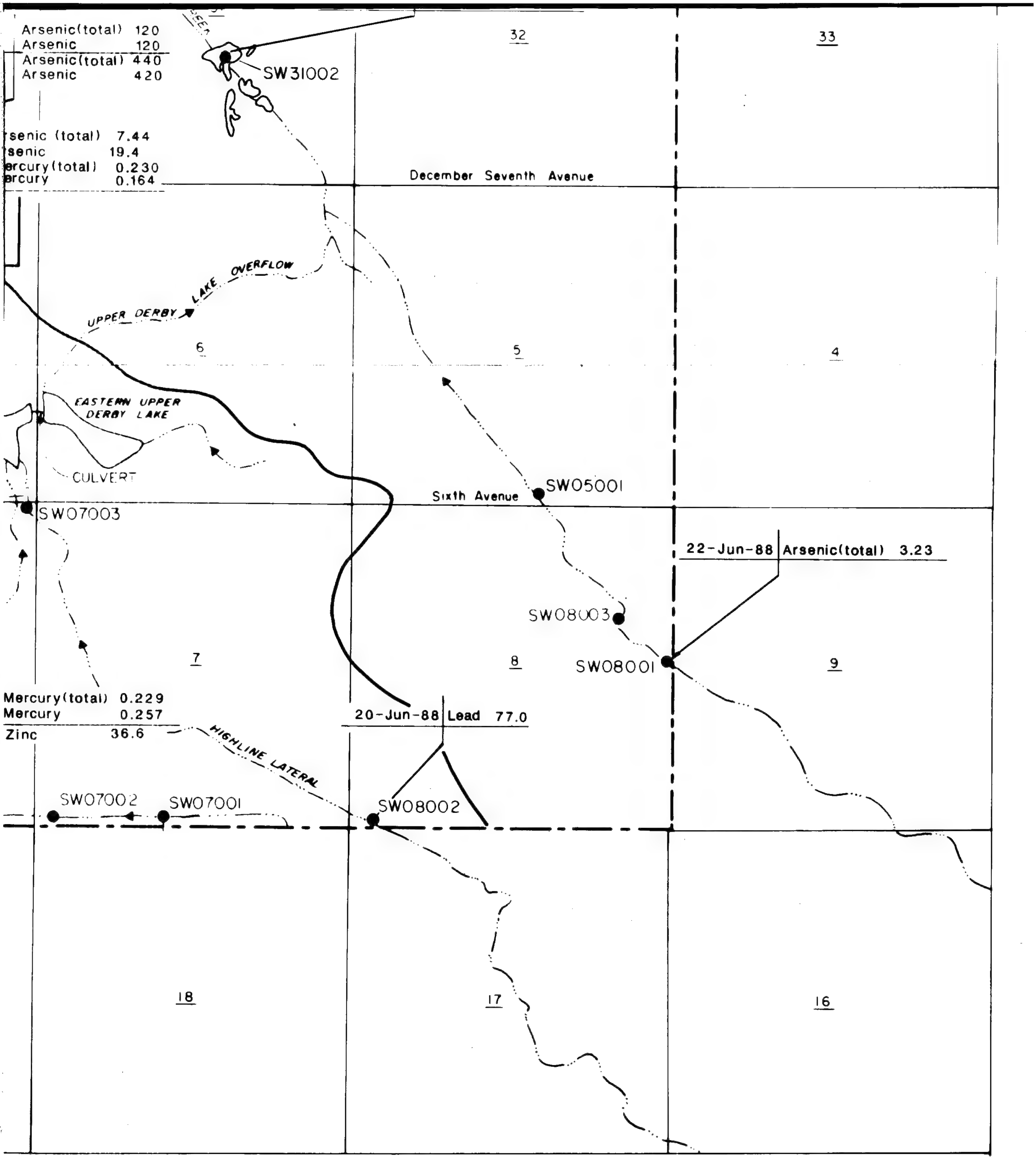
All data reported in micrograms per liter (ug/l).

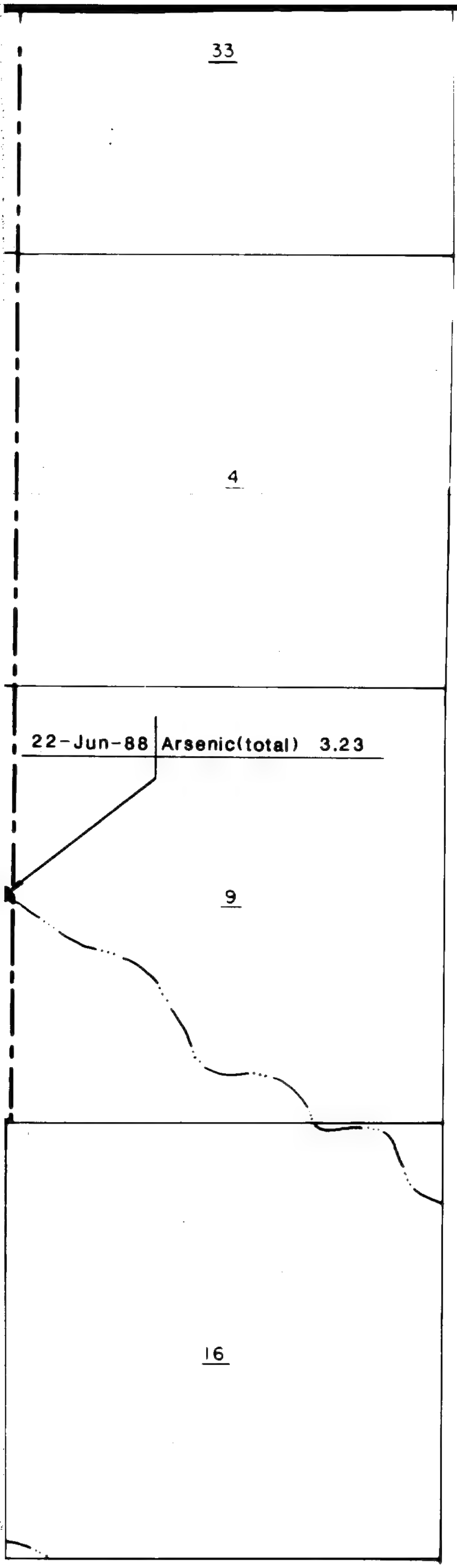


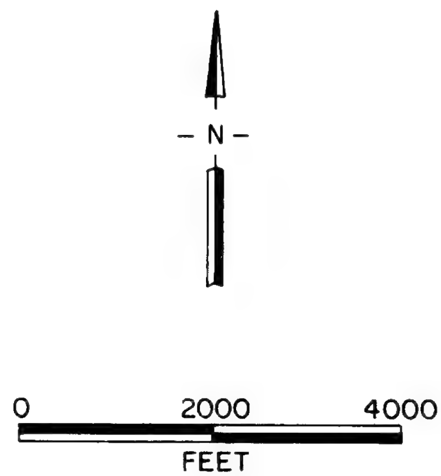
32
33
34
14
SW04001
5
4
3
MOTOR POOL
RAIL CLASSIFICATION YARD
8
9
10
13-Jun-88 Zinc(total)
16-Jul-88 Zinc(total)
Zinc
17
16
15



34
35
BASIN A
15-Jun-88 Arsenic(total) 120
Arsenic 120
04-Oct-88 Arsenic(total) 440
Arsenic 420
06-Oct-88 Mercury(total) 0.200
21-Jun-88 Arsenic (total) 7.44
Arsenic 19.4
Mercury(total) 0.230
Mercury 0.164
SW36001
14-Jun-88 Mercury(total) 0.215
Mercury 0.158
SW02006
SOUTH PLANTS
SW01002
SW02005
SW02003
LAKE MARY
LADORA LAKE
3
UPPER DERBY LAKE
6
UPPER DERBY LAKE
SW01004
EASTERN UPPER DERBY LAKE
SW02001
SW02002
LOWER DERBY LAKE
SW01005
CULVERT
SW01001
SW12003
SW07003
14-Jun-88 Arsenic (total) 3.77
Arsenic 3.45
15-Jun-88 Zinc 126
SAND CREEK LATERAL
ROD and GUN CLUB POND
SW11003
10
11
HAVANA POND
12
UVALDA INTERCEPTOR
7
Zinc(total) 35.1
Zinc(total) 190
Zinc 122
13-Jun-88 Mercury(total) 0.229
Mercury 0.257
19-Jul-88 Zinc 36.6
SW11002
HAVANA INTERCEPTOR
SW11001
PEORIA INTERCEPTOR
SW12006
SW12005
SW12002
SW12001
SW07002
SW12004
20-Jun-88 Zinc(total) 31.6
16-Aug-88 Arsenic(total) 4.74
Arsenic 5.93
Zinc(total) 168
Zinc 120
22-Jun-88 Zinc(total) 23.6
05-Oct-88 Zinc(total) 21.8
Zinc 23.5
15
14
13
18


Arsenic(total) 120
Arsenic 120
Arsenic(total) 440
Arsenic 420
SW31002
32
33
senic (total) 7.44
senic 19.4
ercury(total) 0.230
ercury 0.164
December Seventh Avenue
UPPER DERBY LAKE OVERFLOW
6
5
4
EASTERN UPPER DERBY LAKE
CULVERT
Sixth Avenue
SW05001
SW07003
22-Jun-88 Arsenic(total) 3.23
SW08003
SW08001
7
8
9
Mercury(total) 0.229
Mercury 0.257
Zinc 36.6
20-Jun-88 Lead 77.0
HIGHLINE LATERAL
SW07002
SW07001
SW08002
18
17
16





Prepared for:

U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

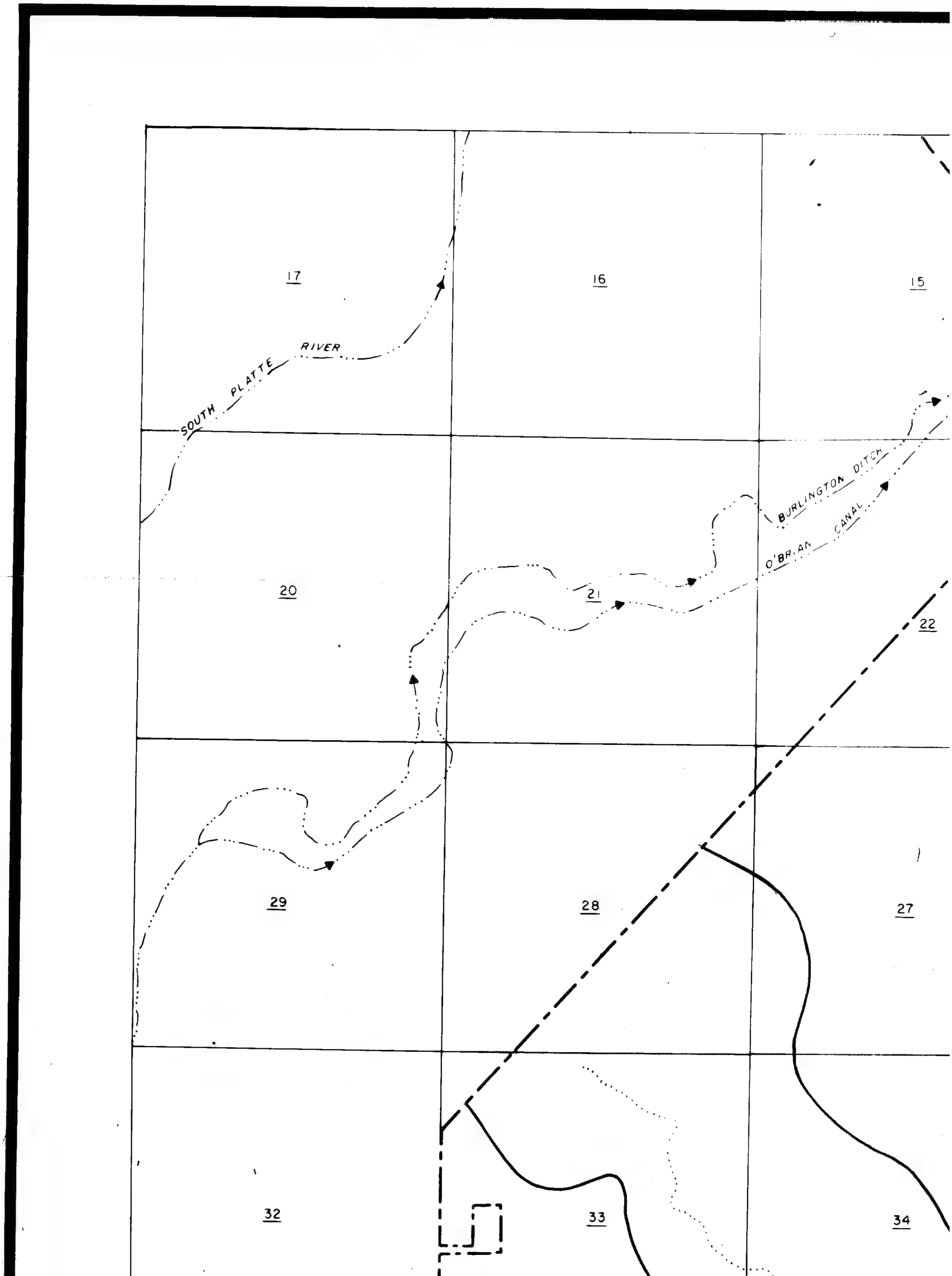
Prepared by:

R.L. Stollar & Associates, Inc.
Harding Lawson Associates

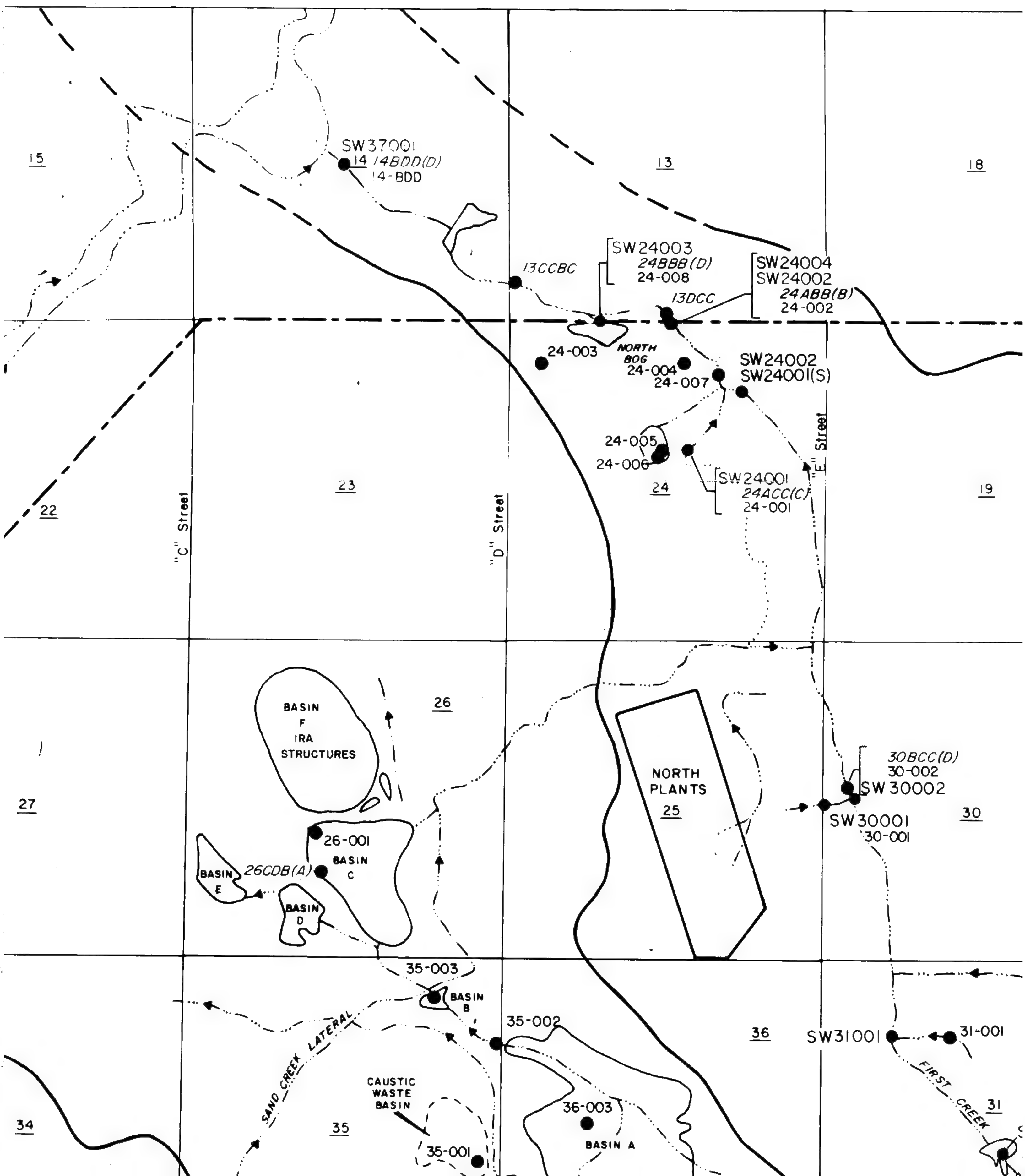
Plate 1.3-4

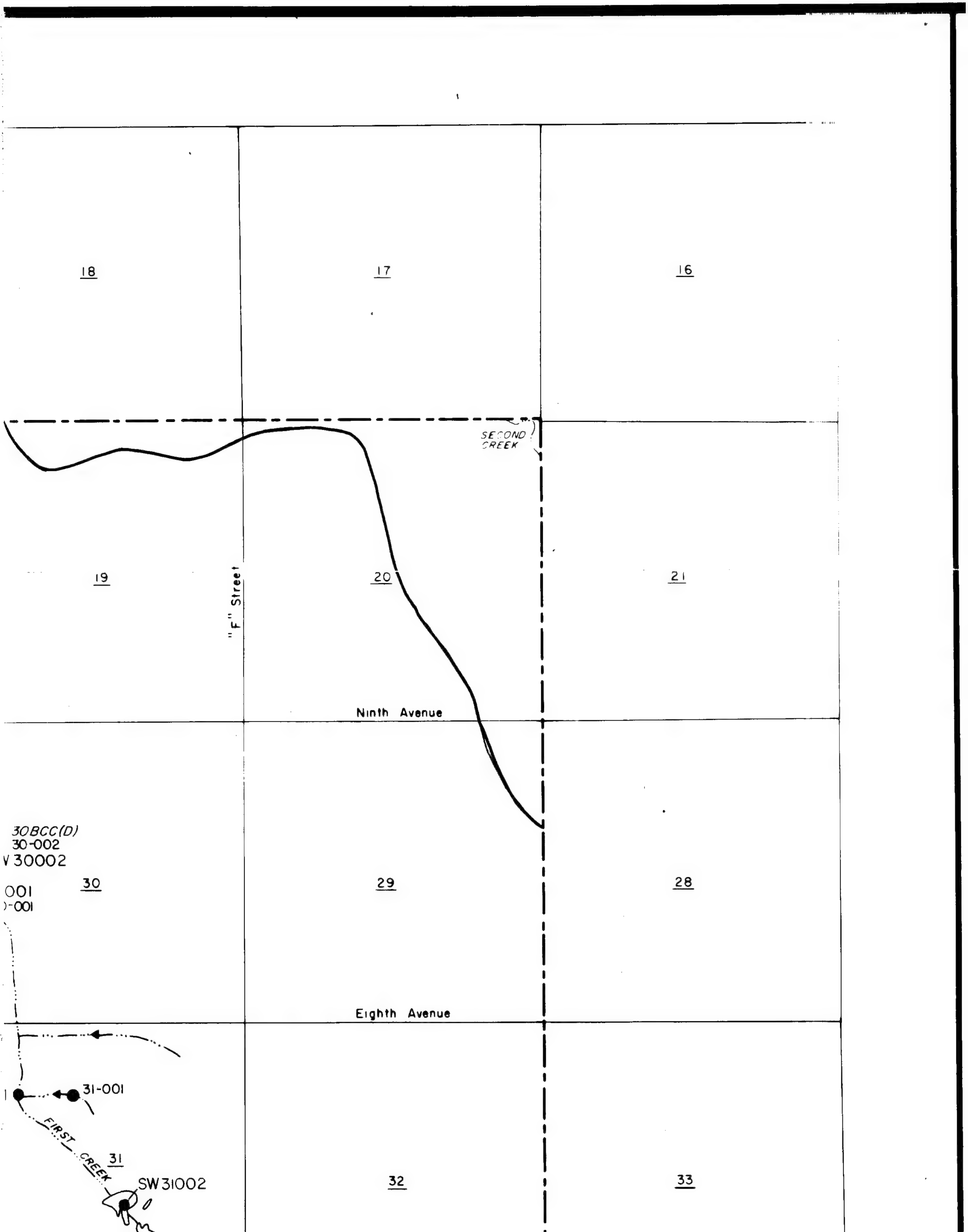
Occurrence of CMP Surface-Water FY88 Trace Inorganic Constituents

CMP SW FY 89

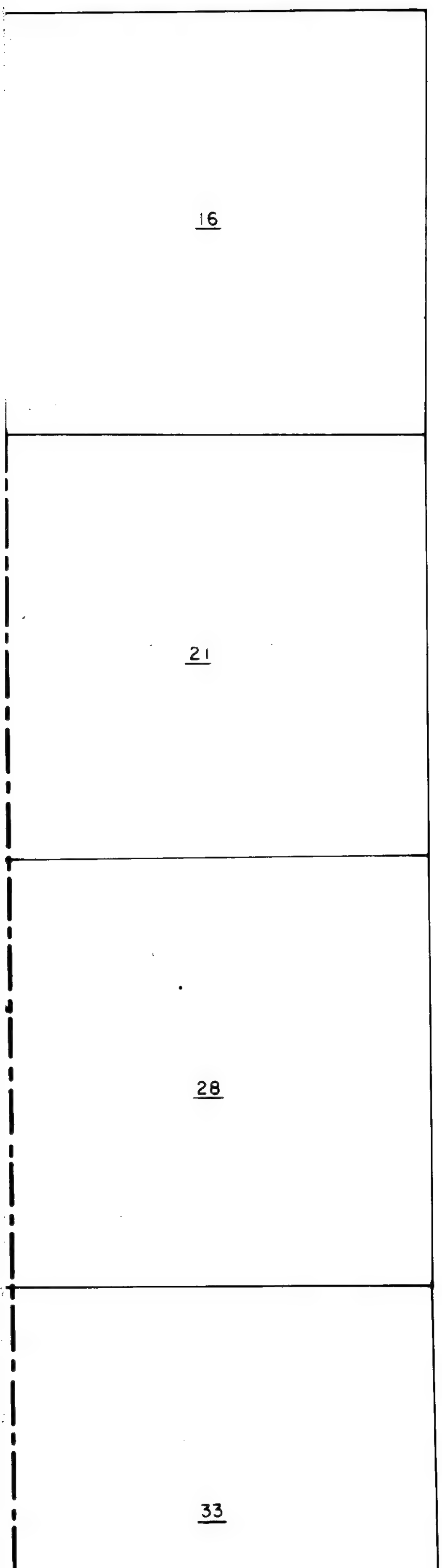


17
16
15
SOUTH PLATTE RIVER
BURLINGTON DITCH
O'BRIAN CANAL
20
21
22
29
28
27
32
33
34


15
SW37001
14 14BDD(D)
14-BDD
13
18
SW24003
24BBB(D)
24-008
13CCBC
SW24004
SW24002
24ABB(B)
24-002
13DCC
24-003
NORTH BOG
24-004
24-007
SW24002
SW24001(S)
24-005
24-006
SW24001
24ACC(C)
24-001
"E" Street
23
24
19
22
"C" Street
"D" Street
BASIN F IRA STRUCTURES
26
27
26-001
BASIN C
26CDB(A)
BASIN E
BASIN D
NORTH PLANTS
25
30BCC(D)
30-002
SW30002
SW30001
30-001
30
35-003
BASIN B
35-002
36
SW31001
31-001
SAND CREEK LATERAL
CAUSTIC WASTE BASIN
36-003
FIRST CREEK
31
34
35
35-001
BASIN A

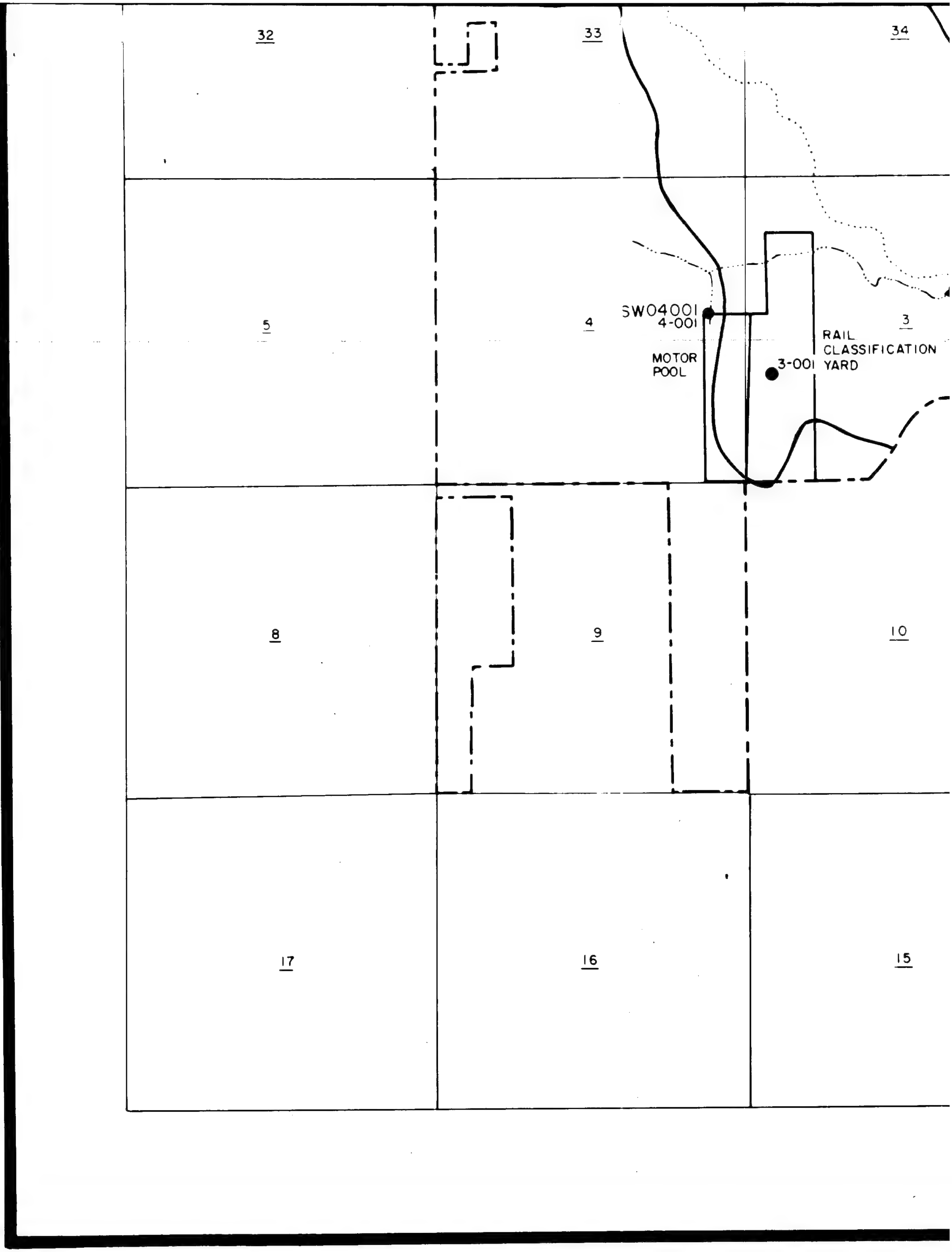


18
17
16
SECOND CREEK
19
"F" Street
20
21
Ninth Avenue
30BCC(D)
30-002
V 30002
001
)-001
30
29
28
Eighth Avenue
31-001
FIRST CREEK
31
SW31002
32
33

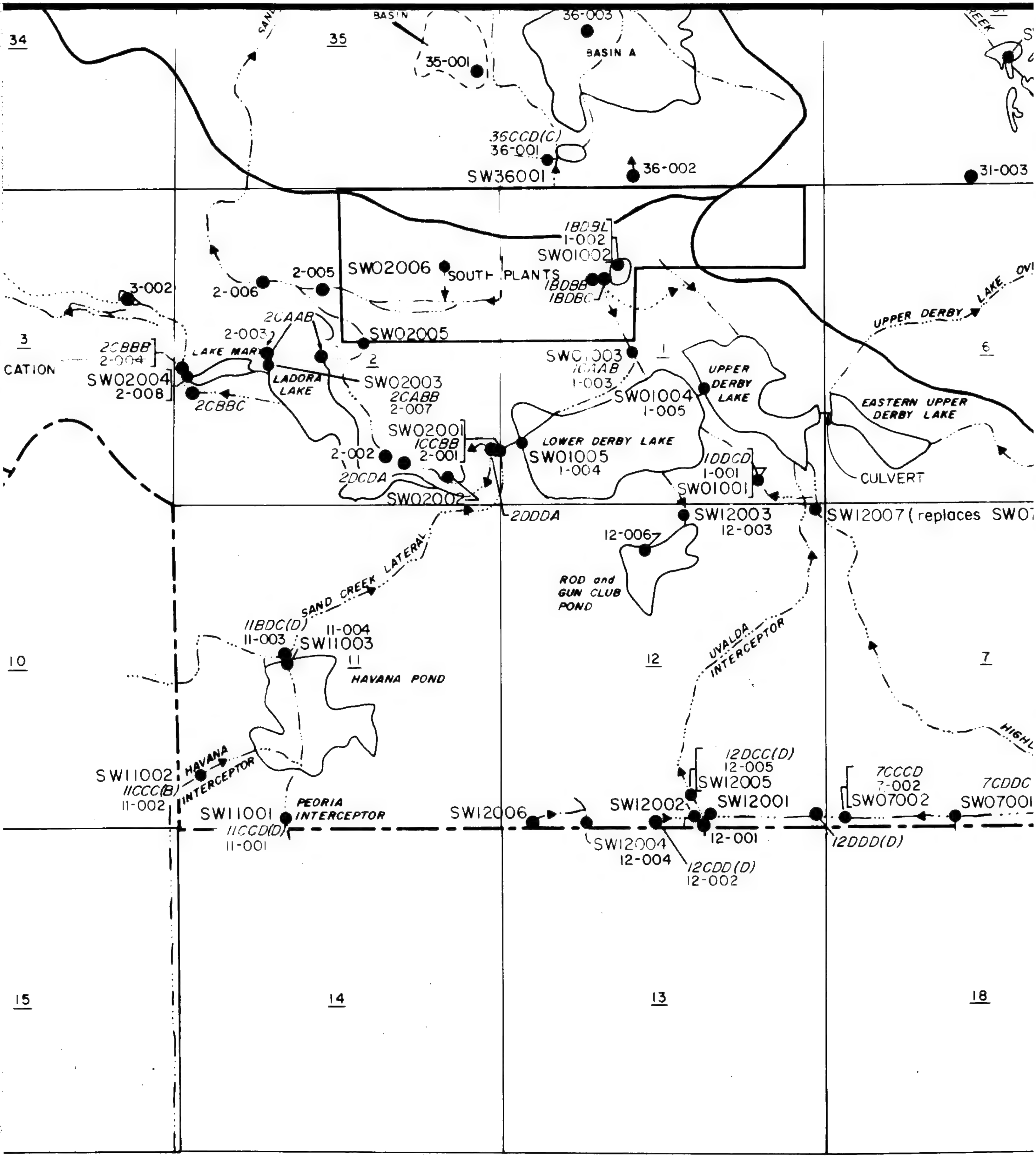


Legend

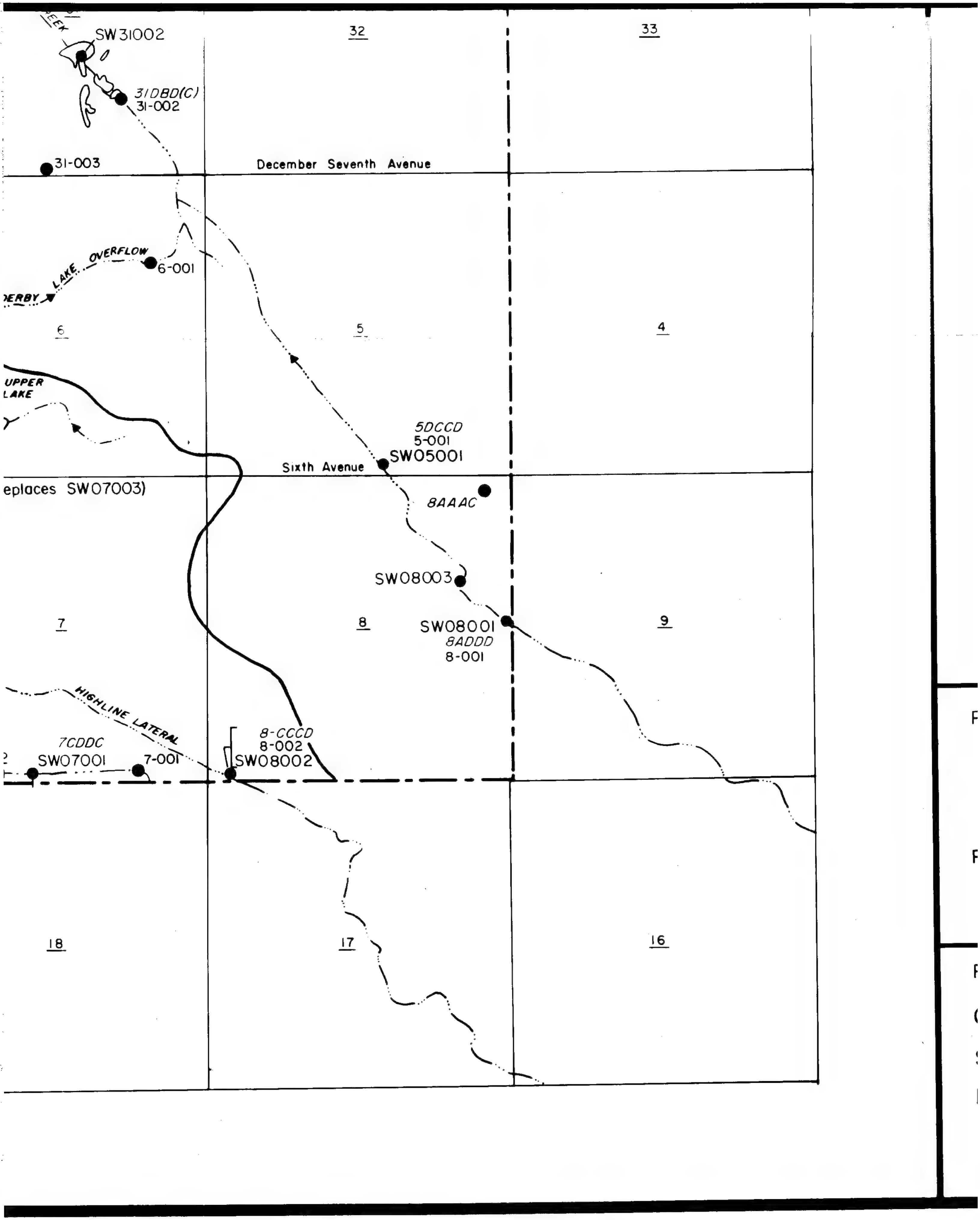
20	Section Number
	Lake, Pond or Basin
	Stream or Ditch with Flow Direction
	Abandoned Stream or Ditch
SW24001	CMP Surface Water Sample Location
24-001	Hunter / ESE Surface Sample Location
24CABB	360° Monitoring Program Sample Location
	Arsenal Boundary
	Drainage Basin Boundary



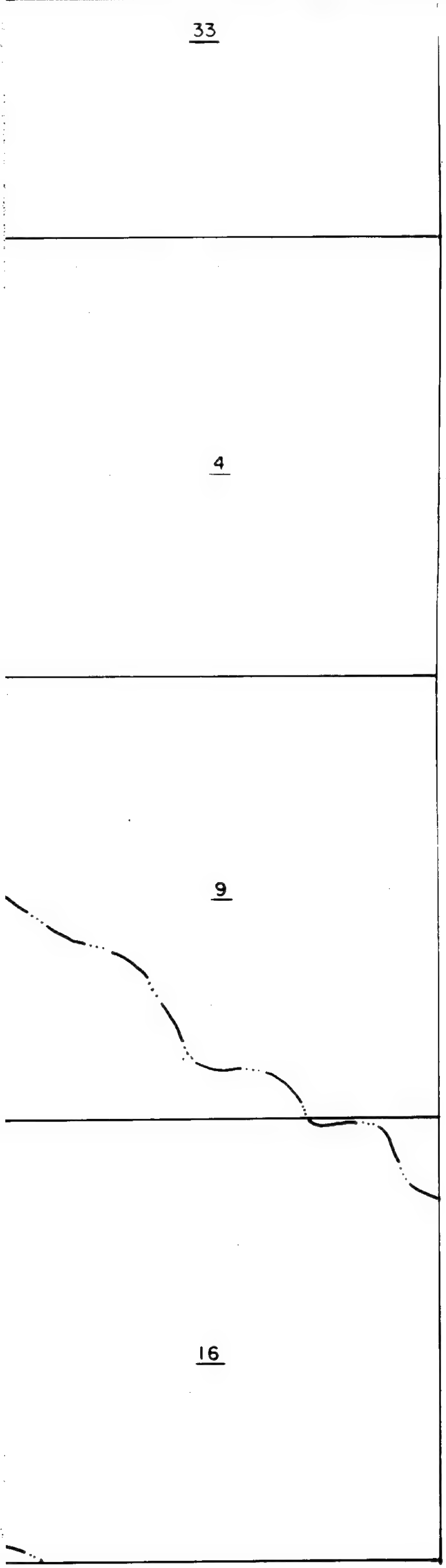
32
33
34
5
4
3
SW04001
4-001
MOTOR
POOL
3-001
RAIL
CLASSIFICATION
YARD
8
9
10
17
16
15

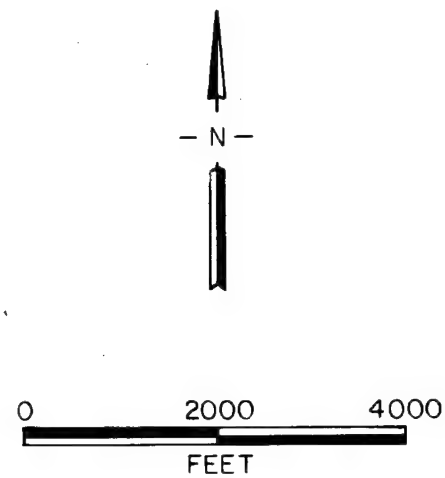


34
35
BASIN
35-001
36-003
BASIN A
36CCD(C)
36-001
SW36001
36-002
31-003
3-002
2-006
2-005
SW02006
SOUTH PLANTS
1BDBL
1-002
SW01002
1BDBB
1BDBC
2CAAB
2-003
2CBBB
2-004
LAKE MARY
LADORA LAKE
SW02005
2
SW01003
1CAAB
1-003
1
UPPER DERBY LAKE
UPPER DERBY LAKE
6
3
CATION
SW02004
2-008
2CBBC
SW02003
2CABB
2-007
SW01004
1-005
EASTERN UPPER DERBY LAKE
SW02001
1CCBB
2-001
2-002
2DCDA
LOWER DERBY LAKE
SW01005
1-004
1DDCD
1-001
SW01001
CULVERT
SW02002
2DDDA
SW12003
12-003
SW12007 (replaces SW07
12-006
ROD and GUN CLUB POND
SAND CREEK LATERAL
11BDC(D)
11-003
11-004
SW11003
11
HAVANA POND
10
12
UVALDA INTERCEPTOR
7
12DCC(D)
12-005
SW12005
7CCCD
7-002
SW07002
7CDDC
SW07001
SW11002
11CCC(B)
11-002
HAVANA INTERCEPTOR
PEORIA INTERCEPTOR
SW11001
11CCD(D)
11-001
SW12006
SW12002
SW12001
12-001
12DDD(D)
SW12004
12-004
12CDD(D)
12-002
15
14
13
18



SW31002
31DBD(C)
31-002
31-003
32
33
December Seventh Avenue
LAKE OVERFLOW
6-001
6
5
4
UPPER LAKE
5DCCD
5-001
SW05001
Sixth Avenue
eplaces SW07003)
8AAAC
SW08003
7
8
9
SW08001
8ADDD
8-001
HIGHLINE LATERAL
7CDDC
SW07001
7-001
8-CCCD
8-002
SW08002
18
17
16





Prepared for:

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

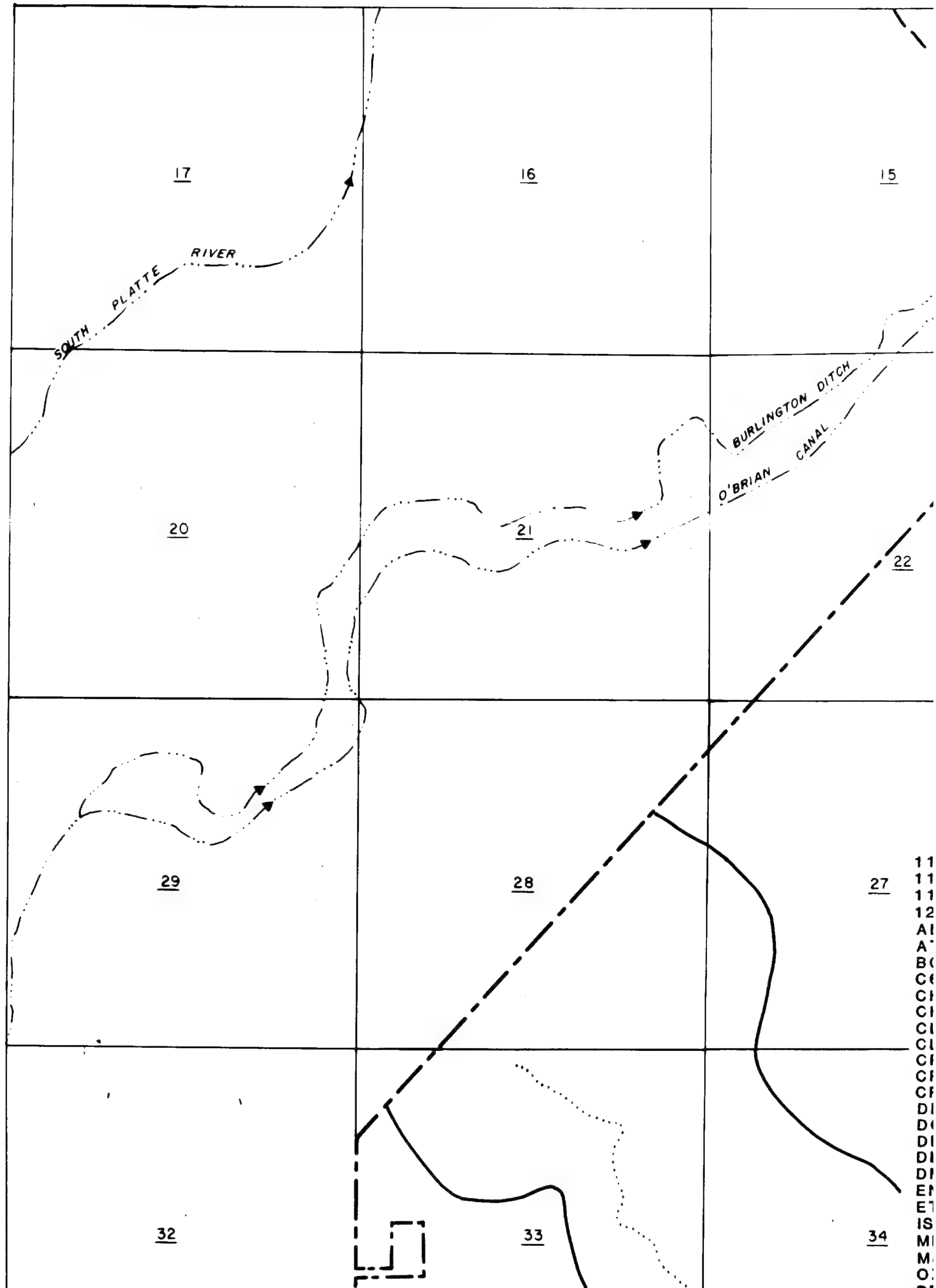
Prepared by:

R.L. Stollar & Associates, Inc.
Harding Lawson Associates

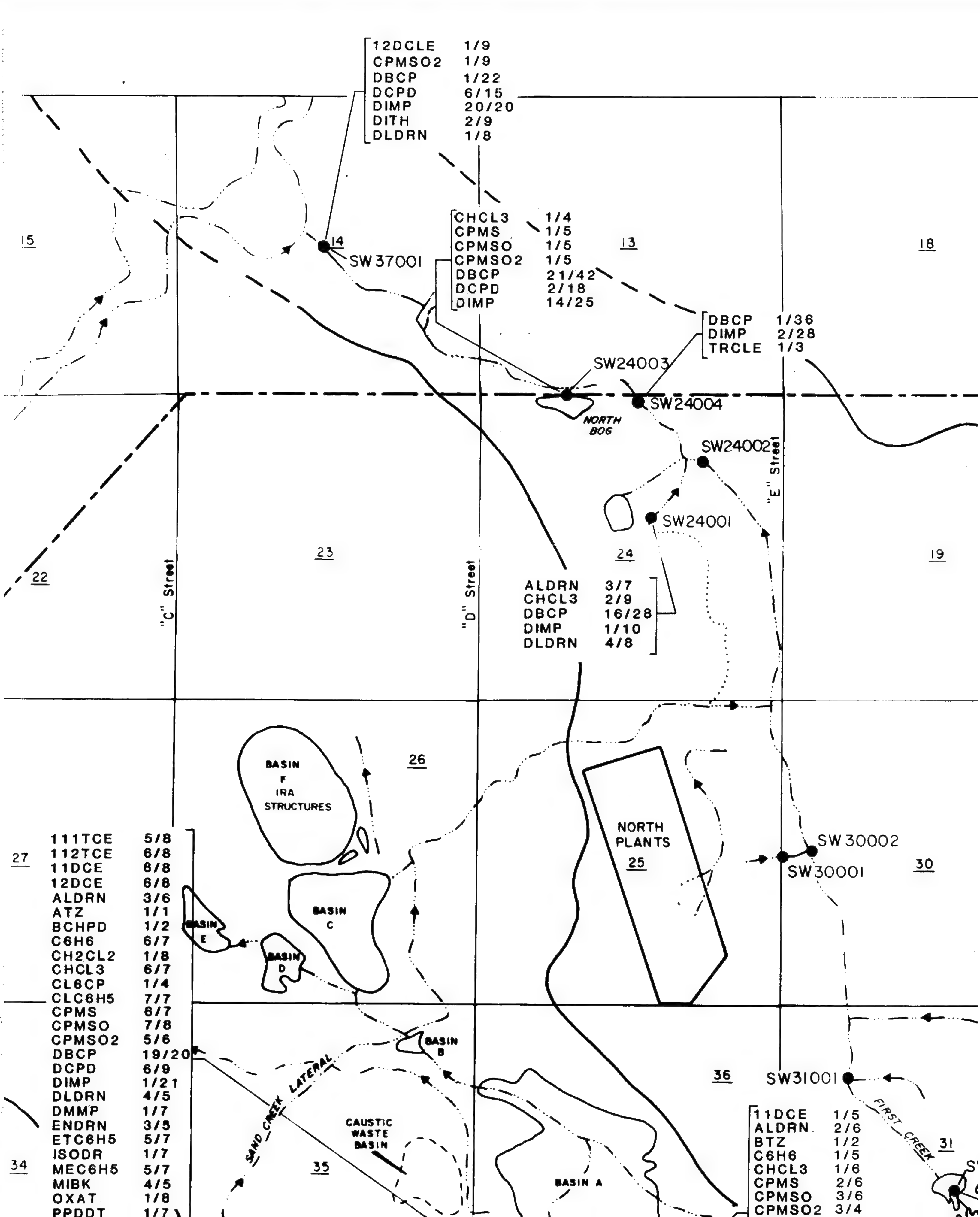
Plate 1.3-5

Correlation of CMP and Historical Surface-Water Quality Sampling Locations

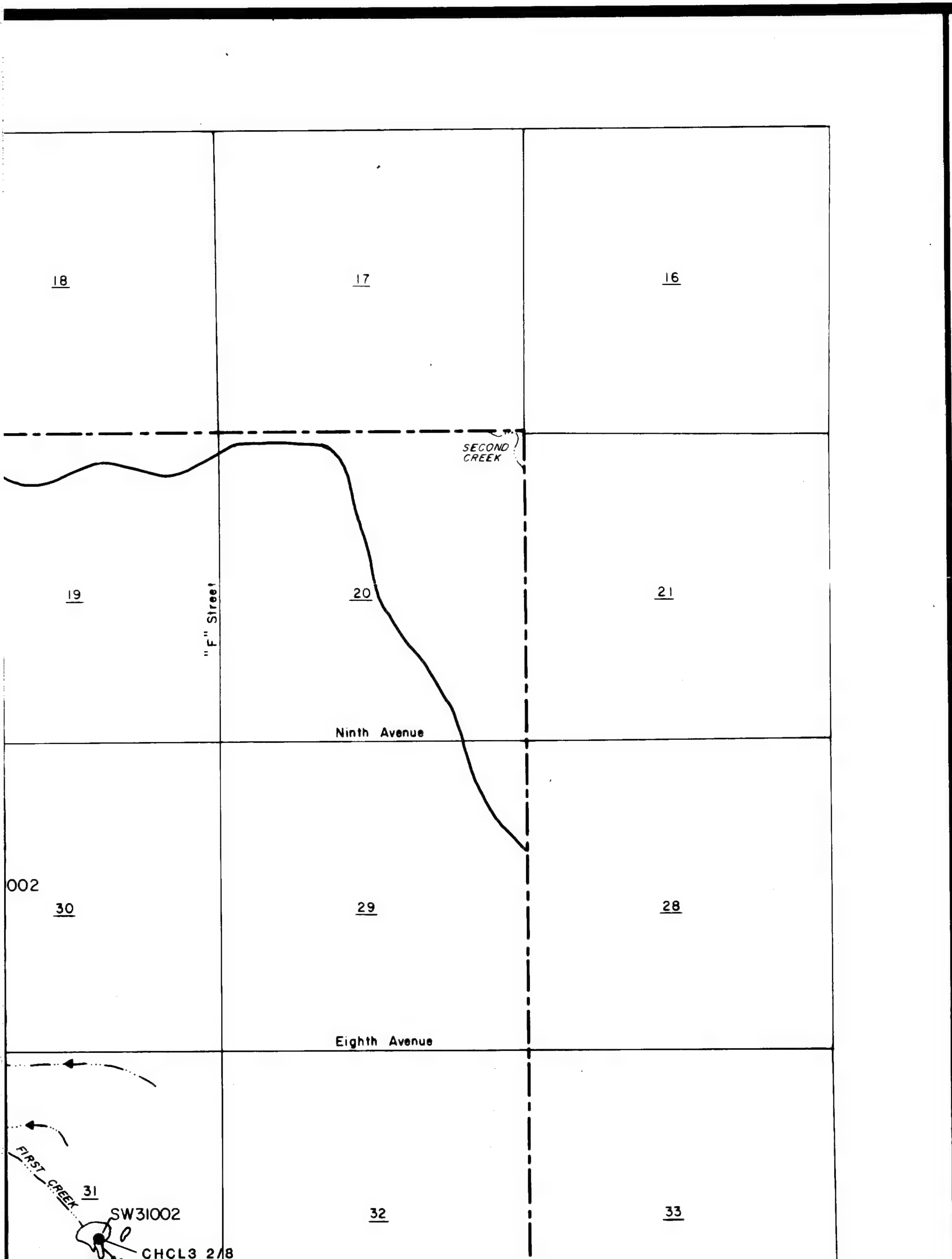
CMP SW FY89



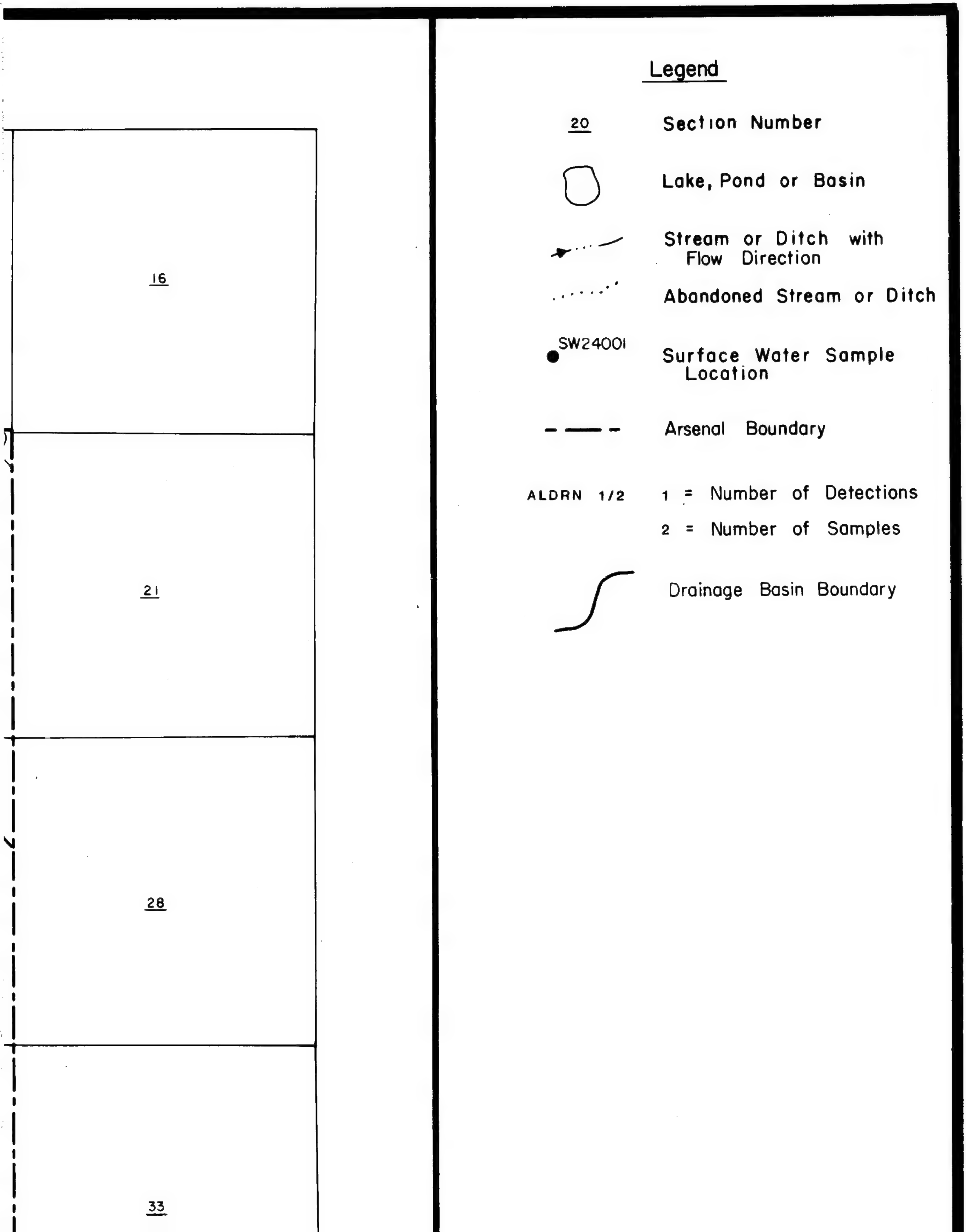
17
16
15
SOUTH PLATTE RIVER
BURLINGTON DITCH
O'BRIAN CANAL
20
21
22
29
28
27
32
33
34



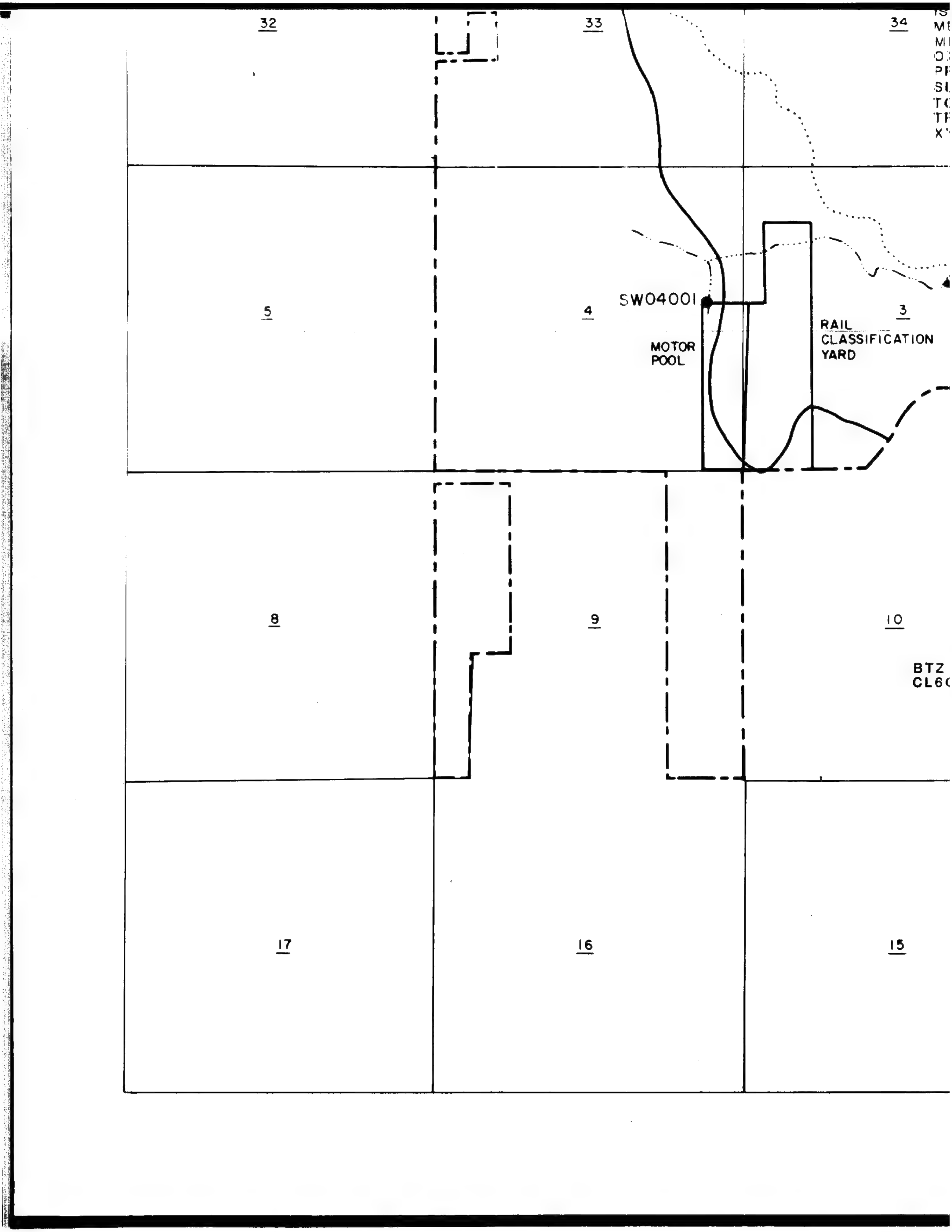
12DCLE 1/9
CPMSO2 1/9
DBCP 1/22
DCPD 6/15
DIMP 20/20
DITH 2/9
DLDRN 1/8
15
14
SW37001
CHCL3 1/4
CPMS 1/5
CPMSO 1/5
CPMSO2 1/5
DBCP 21/42
DCPD 2/18
DIMP 14/25
13
18
DBCP 1/36
DIMP 2/28
TRCLE 1/3
SW24003
SW24004
NORTH BOG
SW24002
"E" Street
SW24001
22
"C" Street
23
"D" Street
24
19
ALDRN 3/7
CHCL3 2/9
DBCP 16/28
DIMP 1/10
DLDRN 4/8
BASIN F IRA STRUCTURES
26
NORTH PLANTS
25
SW30002
SW30001
30
27
111TCE 5/8
112TCE 6/8
11DCE 6/8
12DCE 6/8
ALDRN 3/6
ATZ 1/1
BCHPD 1/2
C6H6 6/7
CH2CL2 1/8
CHCL3 6/7
CL6CP 1/4
CLC6H5 7/7
CPMS 6/7
CPMSO 7/8
CPMSO2 5/6
DBCP 19/20
DCPD 6/9
DIMP 1/21
DLDRN 4/5
DMMP 1/7
ENDRN 3/5
ETC6H5 5/7
ISODR 1/7
MEC6H5 5/7
MIBK 4/5
OXAT 1/8
PPDDT 1/7
34
BASIN E
BASIN D
BASIN C
BASIN B
SAND CREEK LATERAL
CAUSTIC WASTE BASIN
35
BASIN A
36
SW31001
FIRST CREEK
31
11DCE 1/5
ALDRN 2/6
BTZ 1/2
C6H6 1/5
CHCL3 1/6
CPMS 2/6
CPMSO 3/6
CPMSO2 3/4



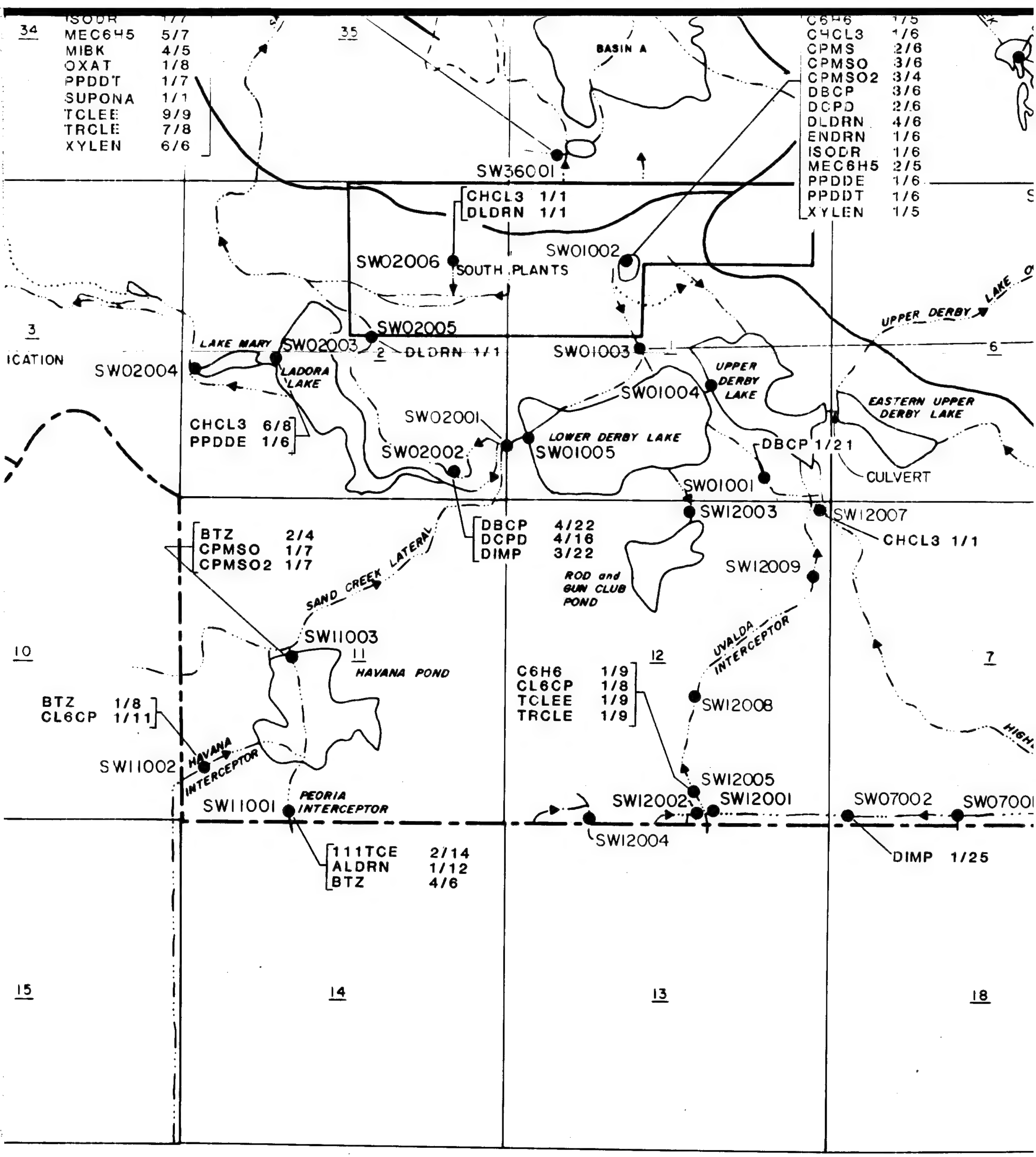
18
17
16
SECOND CREEK
19
"F" Street
20
21
Ninth Avenue
002
30
29
28
Eighth Avenue
FIRST CREEK
31
SW31002
CHCL3 2/8
32
33



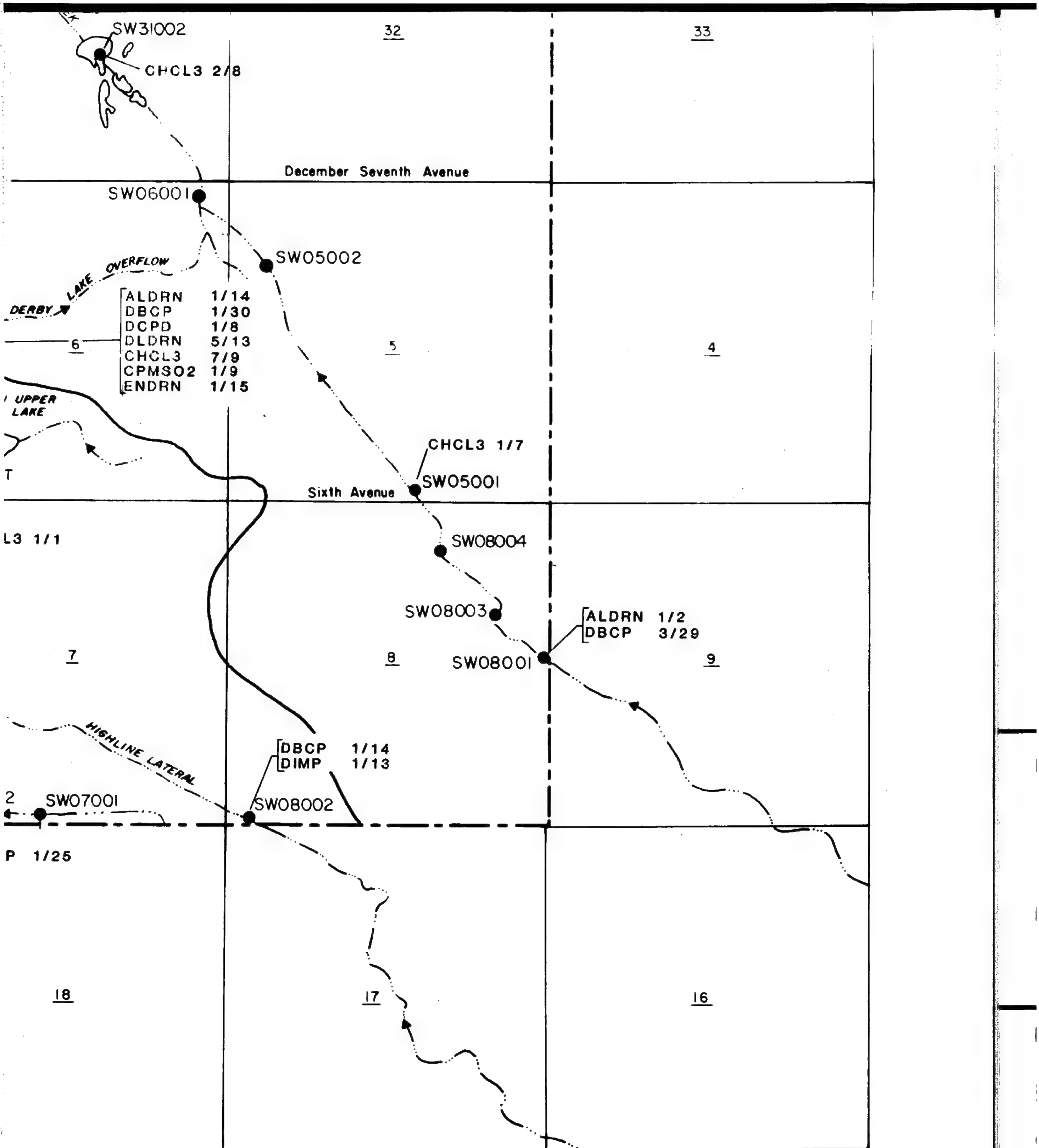
16
21
28
33
Legend
20 Section Number
Lake, Pond or Basin
Stream or Ditch with Flow Direction
Abandoned Stream or Ditch
SW24001
Surface Water Sample Location
Arsenal Boundary
ALDRN 1/2
1 = Number of Detections
2 = Number of Samples
Drainage Basin Boundary



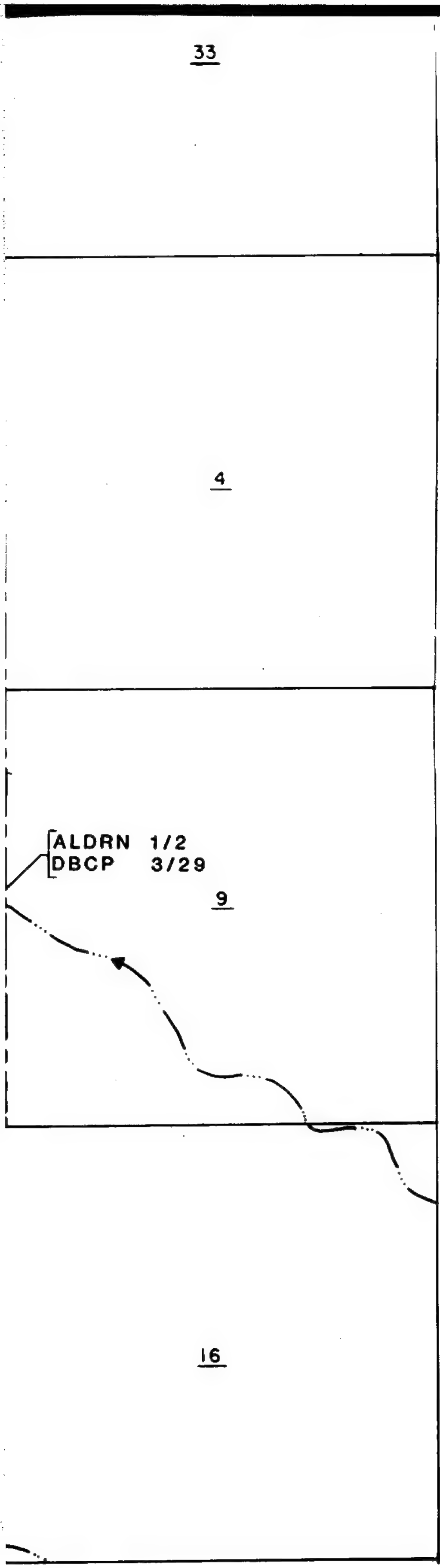
32
33
34
5
4
3
SW04001
MOTOR POOL
RAIL CLASSIFICATION YARD
8
9
10
BTZ
17
16
15

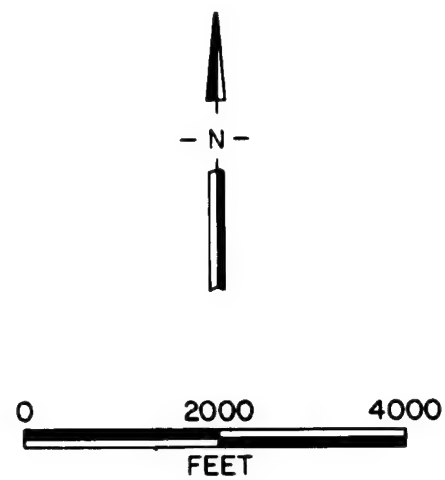


ISODR 1/7
MEC6H5 5/7
MIBK 4/5
OXAT 1/8
PPDDT 1/7
SUPONA 1/1
TCLEE 9/9
TRCLE 7/8
XYLEN 6/6
34
35
BASIN A
C6H6 1/5
CHCL3 1/6
CPMS 2/6
CPMSO 3/6
CPMSO2 3/4
DBCP 3/6
DCPD 2/6
DLDRN 4/6
ENDRN 1/6
ISODR 1/6
MEC6H5 2/5
PPDDE 1/6
PPDDT 1/6
XYLEN 1/5
SW36001
CHCL3 1/1
DLDRN 1/1
SW02006
SOUTH PLANTS
SW01002
3
ICATION
LAKE MARY
SW02003
SW02005
2
DLDRN 1/1
SW01003
1
6
UPPER DERBY LAKE
SW02004
LADORA LAKE
UPPER DERBY LAKE
SW01004
EASTERN UPPER DERBY LAKE
CHCL3 6/8
PPDDE 1/6
SW02001
LOWER DERBY LAKE
SW02002
SW01005
DBCP 1/21
CULVERT
SW01001
SW12003
SW12007
CHCL3 1/1
BTZ 2/4
CPMSO 1/7
CPMSO2 1/7
DBCP 4/22
DCPD 4/16
DIMP 3/22
SAND CREEK LATERAL
ROD and GUN CLUB POND
SW12009
SW11003
10
11
HAVANA POND
12
UVALDA INTERCEPTOR
7
C6H6 1/9
CL6CP 1/8
TCLEE 1/9
TRCLE 1/9
BTZ 1/8
CL6CP 1/11
SW12008
SW11002
HAVANA INTERCEPTOR
SW12005
SW11001
PEORIA INTERCEPTOR
SW12002
SW12001
SW07002
SW07001
SW12004
111TCE 2/14
ALDRN 1/12
BTZ 4/6
DIMP 1/25
15
14
13
18



SW31002
CHCL3 2/8
32
33
December Seventh Avenue
SW06001
SW05002
LAKE OVERFLOW
DERBY
ALDRN 1/14
DBCP 1/30
DCPD 1/8
DLDRN 5/13
CHCL3 7/9
CPMSO2 1/9
ENDRN 1/15
6
5
4
UPPER LAKE
CHCL3 1/7
SW05001
Sixth Avenue
L3 1/1
SW08004
SW08003
ALDRN 1/2
DBCP 3/29
SW08001
7
8
9
HIGHLINE LATERAL
DBCP 1/14
DIMP 1/13
2
SW07001
SW08002
P 1/25
18
17
16





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U.S. Army, Program Manager for
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Commerce City, Colorado

Prepared by :

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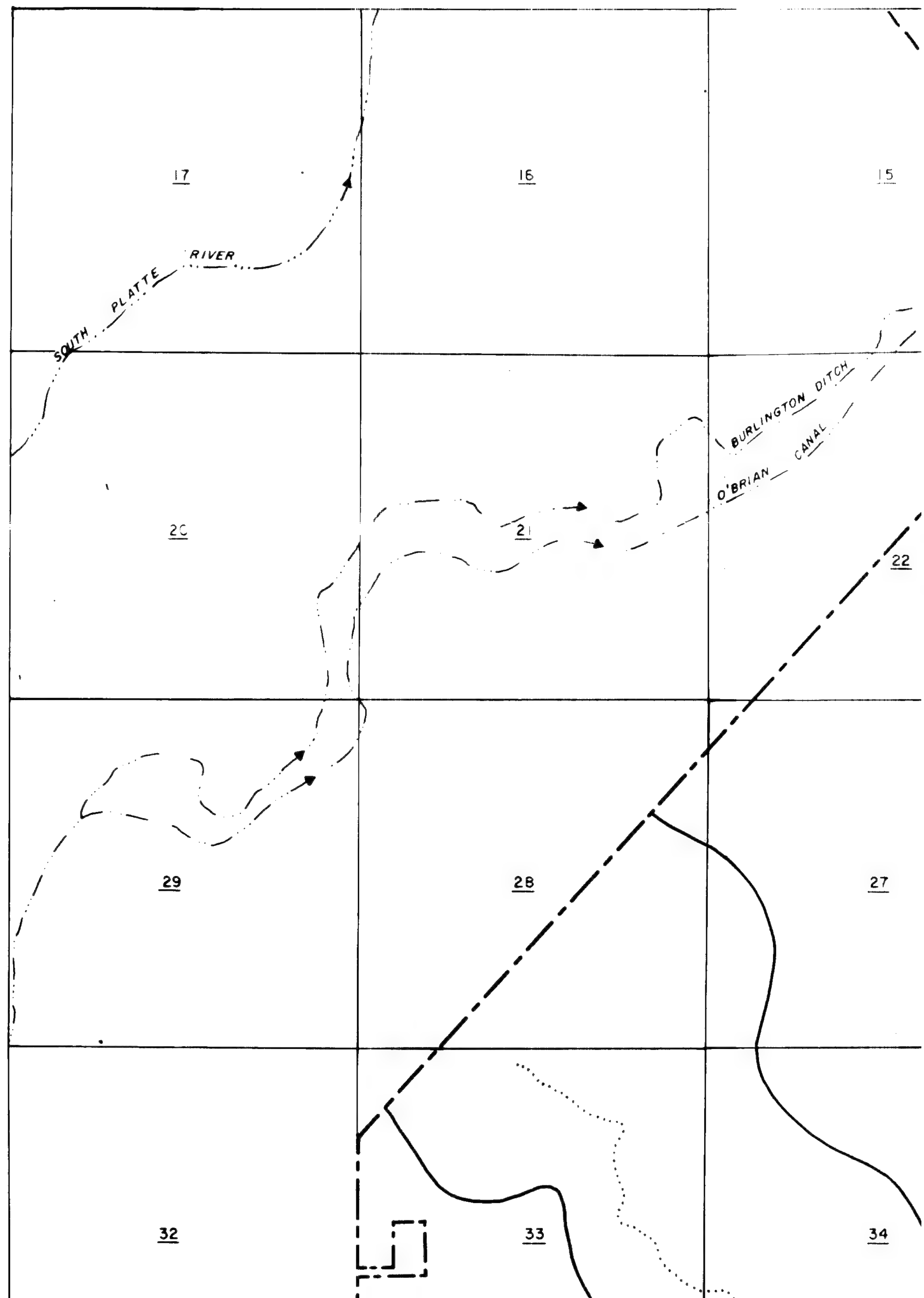
Harding Lawson Associates

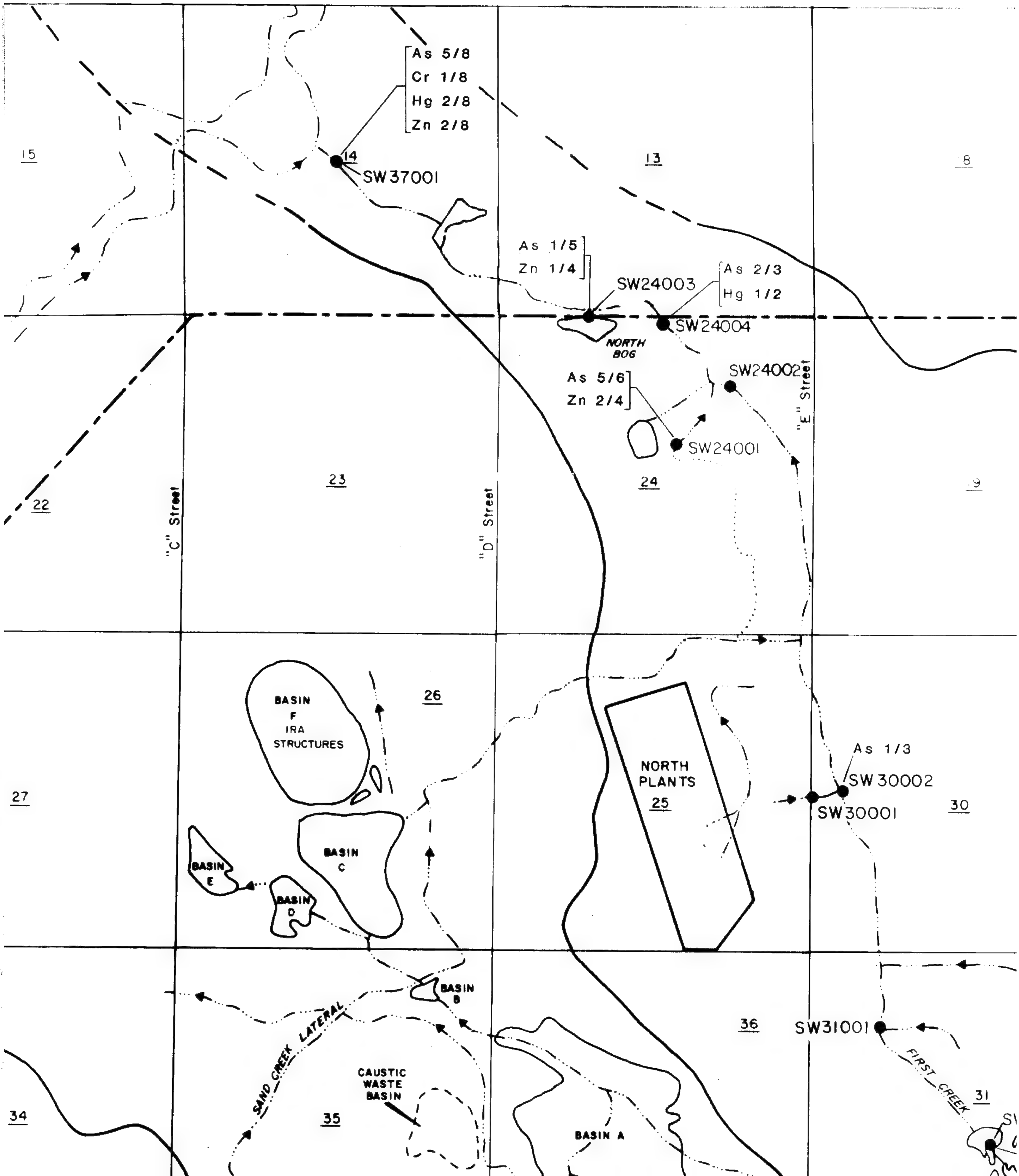
Plate 1.3-6

Frequency of Historical Organic Compound Detections

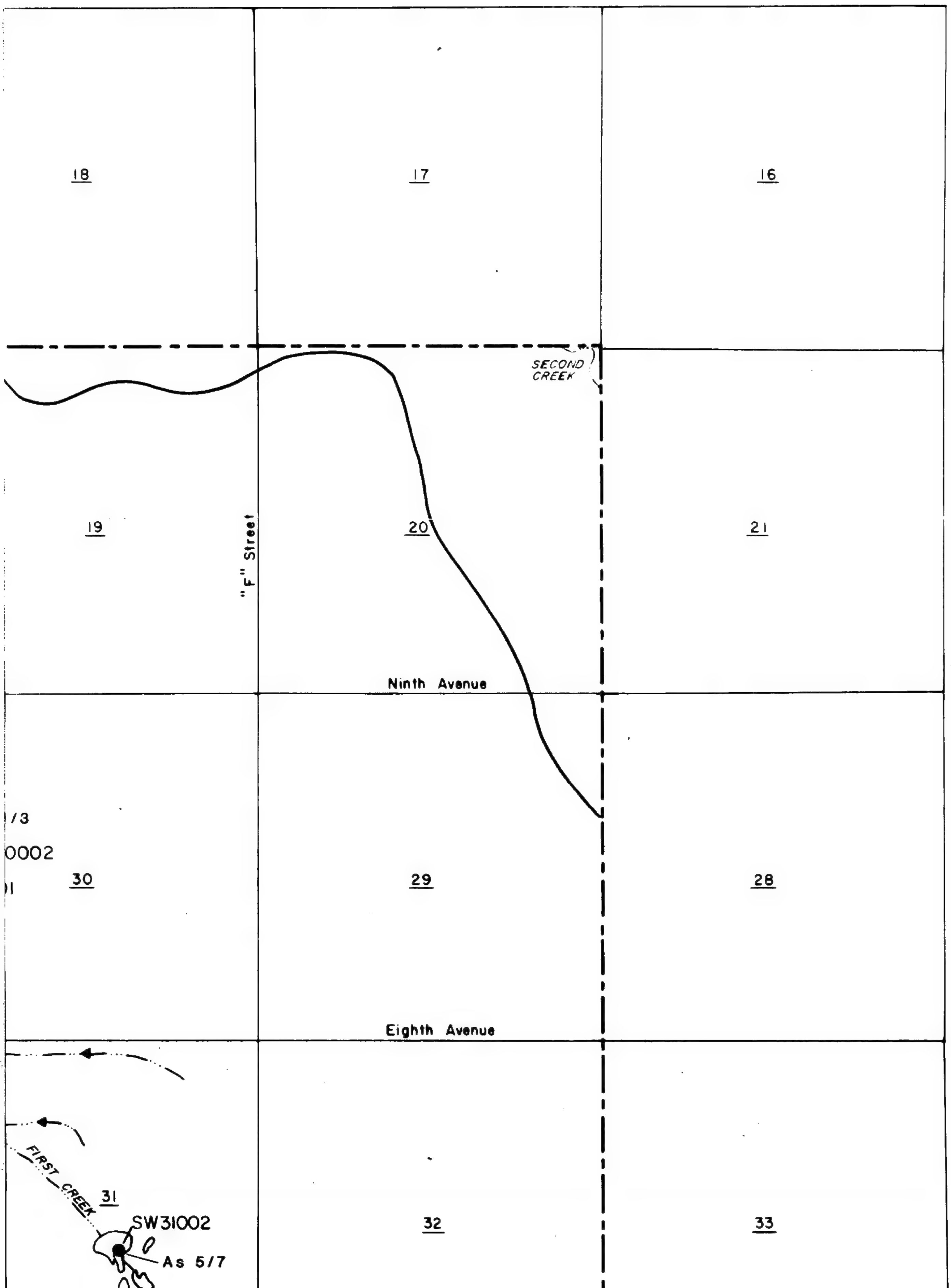
CMP SW FY89

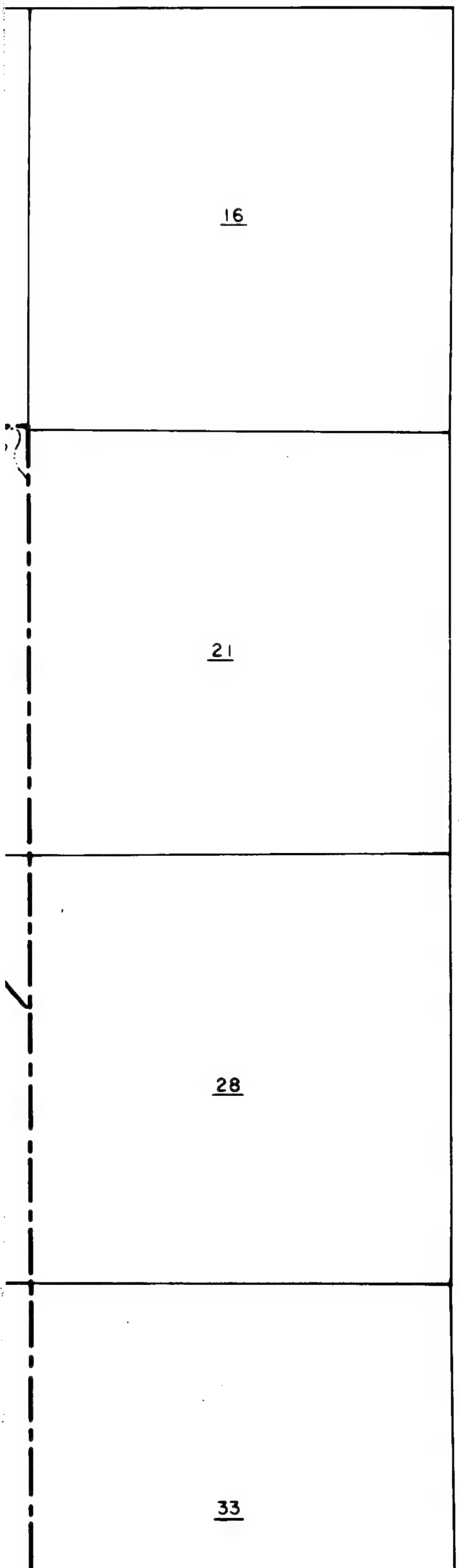


17
16
15
SOUTH PLATTE RIVER
BURLINGTON DITCH
O'BRIAN CANAL
20
21
22
29
28
27
32
33
34



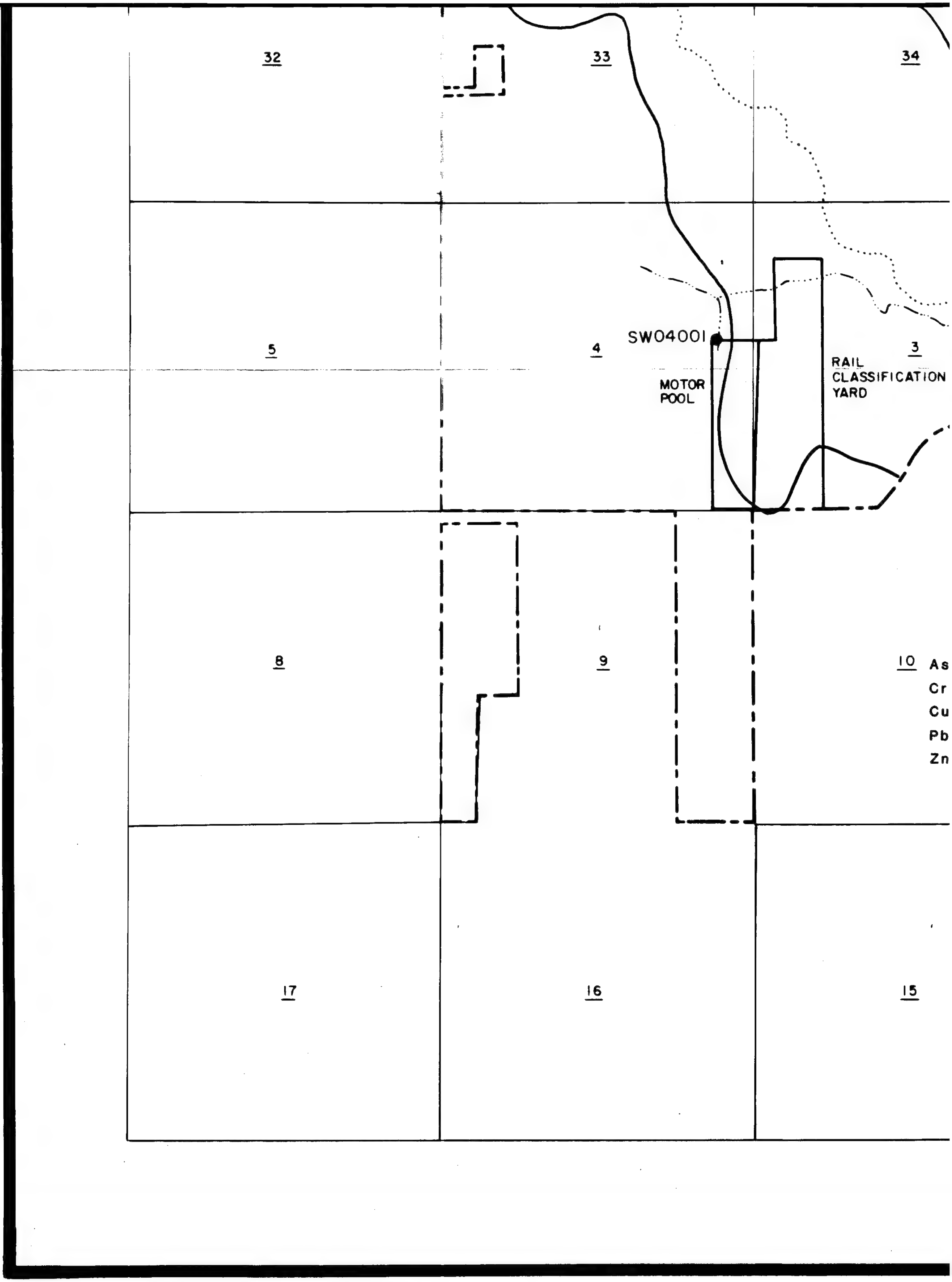
As 5/8
Cr 1/8
Hg 2/8
Zn 2/8
14
SW37001
15
13
8
As 1/5
Zn 1/4
SW24003
As 2/3
Hg 1/2
SW24004
NORTH BOG
As 5/6
Zn 2/4
SW24002
SW24001
"E" Street
23
24
22
9
"C" Street
"D" Street
BASIN F IRA STRUCTURES
26
NORTH PLANTS
25
As 1/3
SW 30002
SW30001
30
27
BASIN E
BASIN C
BASIN D
BASIN B
36
SW31001
FIRST CREEK
SAND CREEK LATERAL
CAUSTIC WASTE BASIN
34
35
BASIN A
31


18
17
16
SECOND CREEK
19
"F" Street
20
21
Ninth Avenue
/3
0002
30
29
28
Eighth Avenue
FIRST CREEK
31
SW31002
As 5/7
32
33

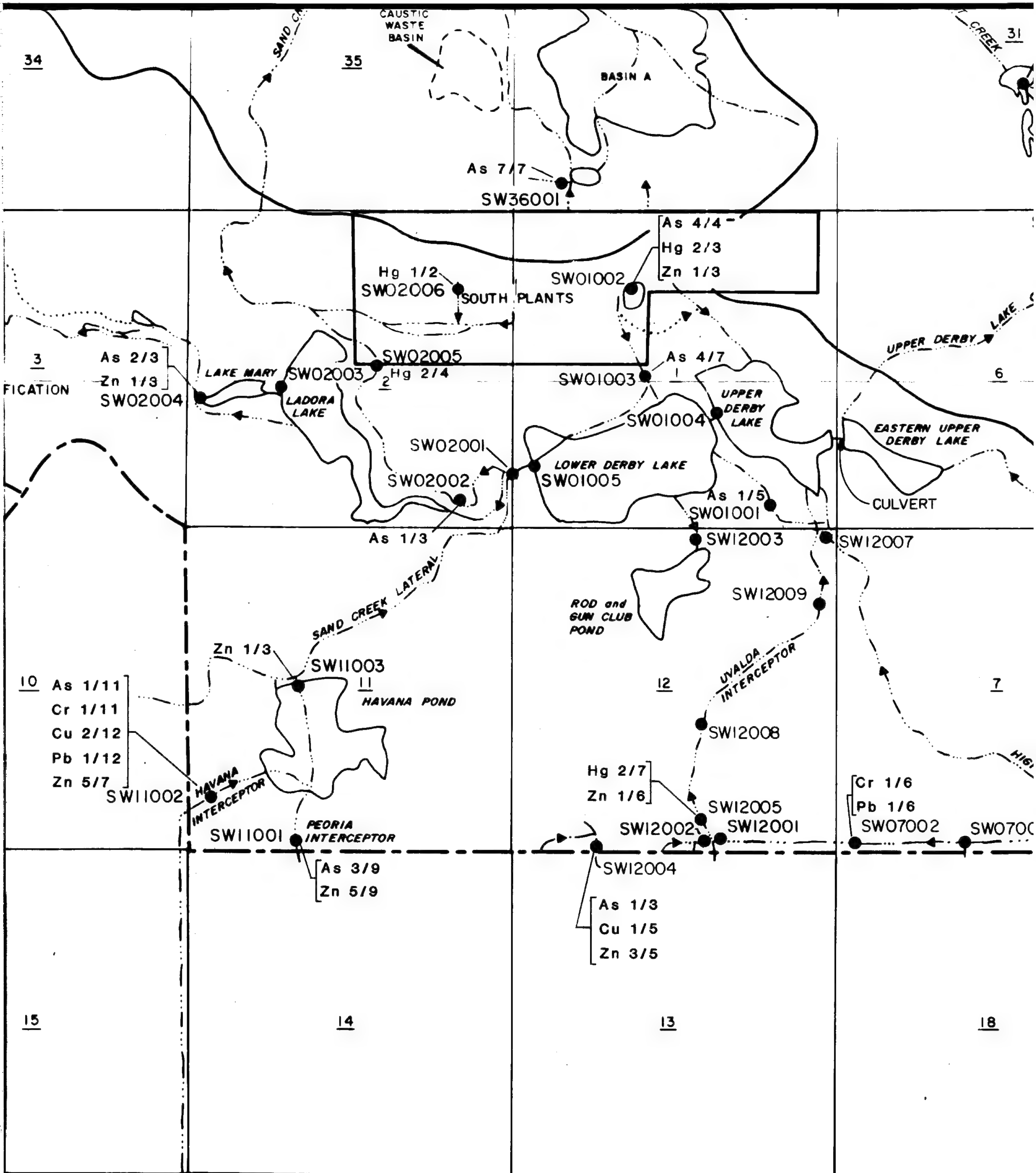


Legend

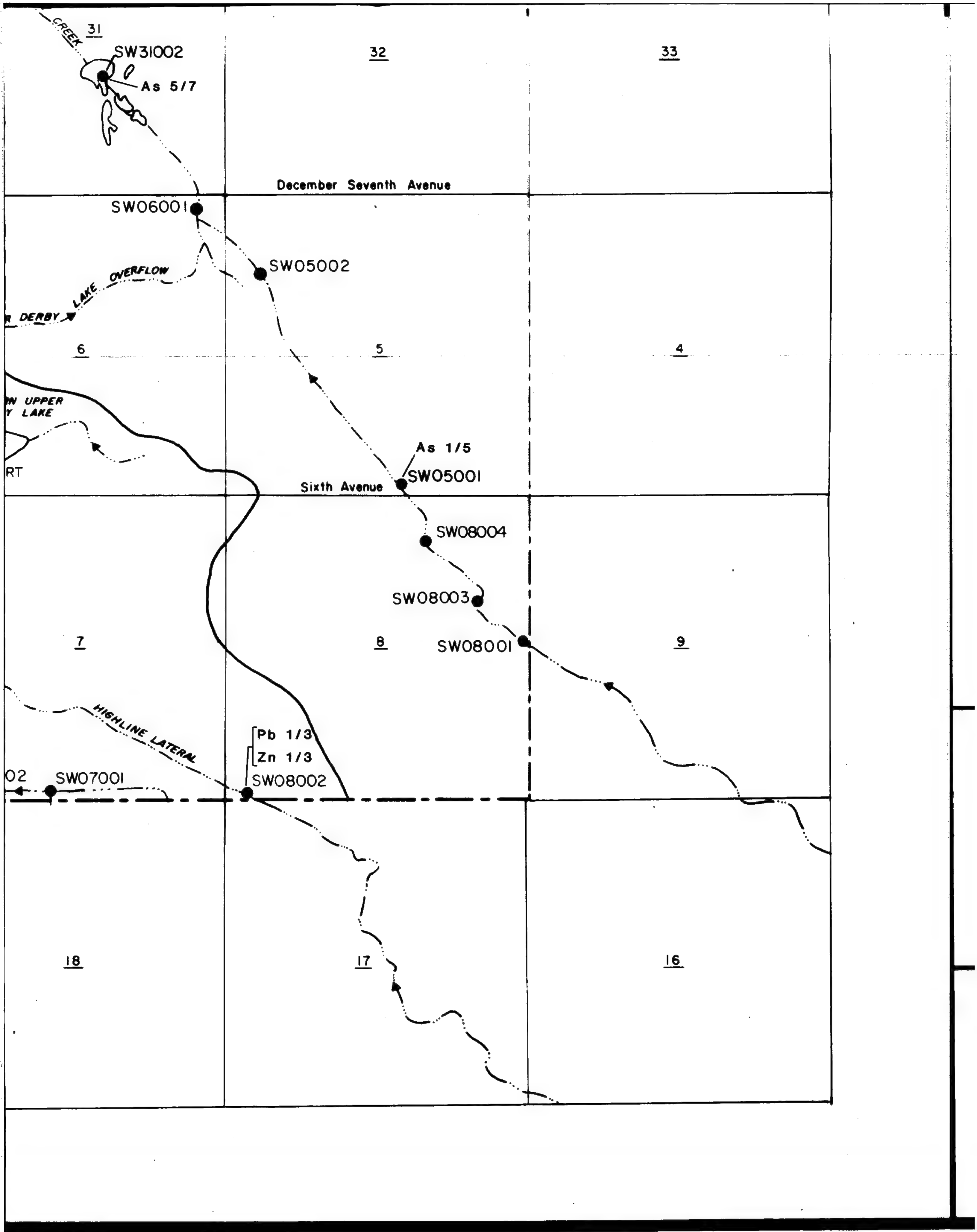
20	Section Number
	Lake, Pond or Basin
	Stream or Ditch with Flow Direction
	Abandoned Stream or Ditch
SW24001	Surface Water Sample Location
	Arsenal Boundary
As 1/3	1 = Number of Detections
	3 = Number of Samples
	Drainage Basin Boundary

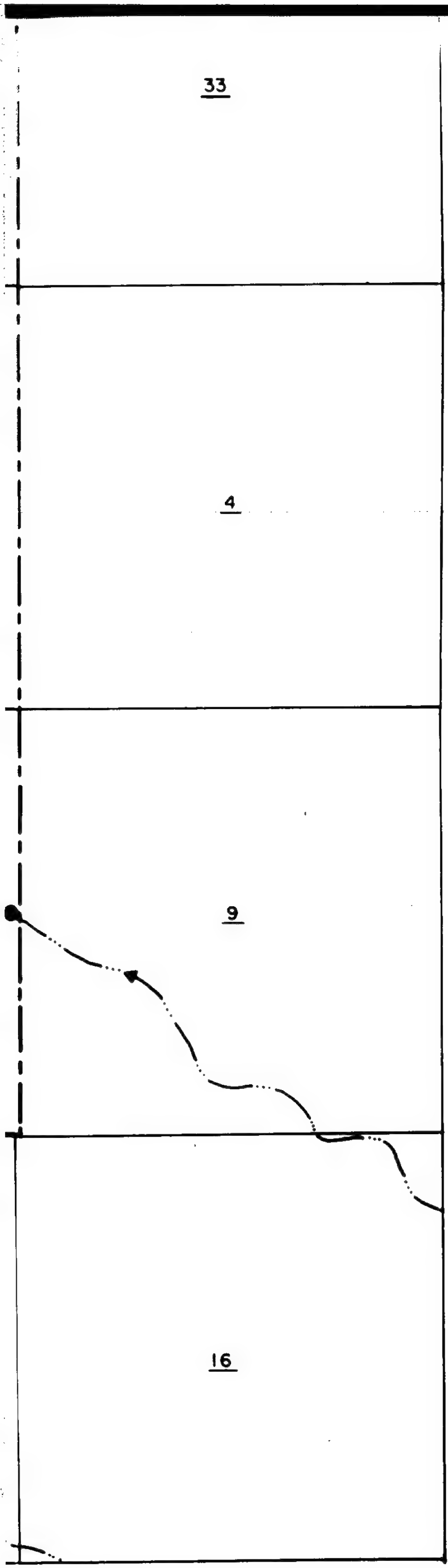


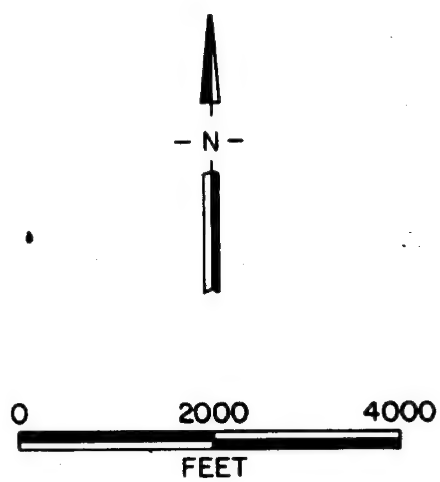
32
33
34
5
4
3
SW04001
MOTOR
POOL
RAIL
CLASSIFICATION
YARD
8
9
10
As
Cr
Cu
Pb
Zn
17
16
15



CAUSTIC WASTE BASIN
34
35
31
SAND CREEK
CREEK
BASIN A
As 7/7
SW36001
As 4/4
Hg 2/3
Zn 1/3
Hg 1/2
SW02006
SOUTH PLANTS
SW01002
SW02005
Hg 2/4
As 4/7
SW01003
3
As 2/3
Zn 1/3
SW02004
LAKE MARY
SW02003
LADORA LAKE
FICATION
UPPER DERBY LAKE
UPPER DERBY
LAKE
EASTERN UPPER DERBY LAKE
6
SW01004
SW02001
LOWER DERBY LAKE
SW01005
SW02002
As 1/5
SW01001
CULVERT
As 1/3
SW12003
SW12007
SAND CREEK LATERAL
ROD and GUN CLUB POND
SW12009
Zn 1/3
SW11003
11
HAVANA POND
10
As 1/11
Cr 1/11
Cu 2/12
Pb 1/12
Zn 5/7
SW11002
HAVANA INTERCEPTOR
UVALDA INTERCEPTOR
12
7
SW12008
Hg 2/7
Zn 1/6
SW12005
SW12002
SW12001
Cr 1/6
Pb 1/6
SW07002
SW0700
SW11001
PEORIA INTERCEPTOR
As 3/9
Zn 5/9
SW12004
As 1/3
Cu 1/5
Zn 3/5
15
14
13
18


CREEK
31
SW31002
As 5/7
32
33
December Seventh Avenue
SW06001
SW05002
LAKE OVERFLOW
DERBY
6
5
4
UPPER
LAKE
RT
As 1/5
SW05001
Sixth Avenue
SW08004
SW08003
7
8
SW08001
9
HIGHLINE LATERAL
Pb 1/3
Zn 1/3
02
SW07001
SW08002
18
17
16





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U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

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Harding Lawson Associates

Plate 1.3-7

Frequency of Historical Trace Inorganic Constituent Detections

CMP SW FY89

2.0 ENVIRONMENTAL SETTING

Surface water is only one component in the interacting hydrogeologic system at RMA. Weather, geology, physiography, man-made structures, and man's activities all have varying influences on the characteristics of the surface-water system. Section 2.0 provides a description of these components and some of their influences. A brief historical review of the development of each of the major surface-water features at RMA and their physical characteristics and interrelationships is also provided. This section also discusses the major drainage basins that exist on and near the RMA facility.

2.1 General Setting

RMA lies within the High Plains physiographic province. Topography at the Arsenal is characterized by gently rolling hills with intermittent depressions occurring mostly in its west and northwest portion. Surface elevation ranges from approximately 5,340 ft above mean sea level (ft-msl) in the southeast corner of RMA to 5,140 ft above msl along the southwest boundary. The overall topographic surface slopes to the northwest towards the South Platte River. First Creek is the only drainage which transects and flows through the entire Arsenal. The stream drops in elevation about 160 ft along its course at RMA.

The climate at RMA is similar to that of much of the central Rocky Mountain Region. The area generally experiences low relative humidity, light precipitation and abundant sunshine. March and early April are the windiest and wettest months of the year, with much of the precipitation in the form of snow. Historical climatological records (1958-1987) collected at Stapleton Airport (NOAA, 1987) indicate snowfall during these months ranges from 9.3 to 12.8 inches, with 1.13 to 1.99 inches of precipitation occurring in the form of rainfall. The month of May historically receives the most rain, averaging 2.41 inches. Summer precipitation falls principally from scattered thunderstorms during the afternoon and evening. Severe thunderstorms with large hail and heavy rain occasionally occur. Autumn is relatively dry with few thunderstorms and abundant sunshine. Historical mean average temperatures range from 30.1° F in January to 72.8° F in July. Large temperature variations can occur in the winter resulting from invasions of cold arctic air from the north, or warm Chinook winds from the west.

The two uppermost geologic units underlying RMA consist of Pleistocene to recent alluvial and eolian deposits and the Cretaceous to Tertiary Denver Formation. Unconsolidated Quaternary deposits are composed principally of fluvial sediments deposited by the ancestral South Platte River system, covered in part by wind-blown sediments. Eolian material varies in thickness to a

maximum of 50 ft and consists of very fine to silty sand, sandy silt and clay (MKE, 1988). Alluvial deposits consist predominantly of sands and gravels, which normally vary in thickness from approximately 50 to 130 ft. Alluvium increases in thickness where deposition has occurred in paleochannels present on the surface of the Denver Formation. Areas with less than 20 ft of alluvial and eolian deposits occur across RMA, mainly in areas overlying bedrock highs (Ebasco Services, Inc., et al., 1989a).

The underlying Denver Formation is composed of interbedded bentonitic claystone, sandstone, siltstone, lignite and volcaniclastic deposits. Many of the beds are rich in plant remains and carbonaceous material. Sandstones are lenticular and laterally discontinuous. Individual sandstone intervals range in thickness from a few inches up to 65 ft. Data suggest the total thickness of the Denver Formation underlying RMA is approximately 200 - 500 feet (MKE, 1988). Denver Formation strata display a regional dip of approximately 1° to the Southeast, resulting in relatively older stratigraphic zones subcropping against alluvium in the northwest portion of RMA, and progressively younger zones subcropping in the Southeast. Quaternary sediments and the upper permeable portions of the Denver Formation are in hydraulic communication and form the unconfined ground-water system (Ebasco Services, Inc., et al., 1989a).

2.2 Ground-Water Hydrology

The ground-water system contributes significantly to the physical and chemical characteristics displayed by surface-water at some RMA locations. An evaluation of the interaction occurring between surface-water and ground water in certain areas across RMA is provided in Section 4.4. The following discussion is a brief synopsis of the general characteristics of the ground-water system at RMA.

Ground water at RMA occurs under both confined and unconfined conditions. Unconfined flow occurs in saturated portions of the eolian and alluvial Quaternary deposits and the uppermost permeable subcropping portion of the underlying Denver Formation. In areas where material making up the Quaternary deposits are unsaturated, the unconfined flow system consists solely of sandstone and fractured or weathered rock within the upper portion of the Denver Formation. Saturated thickness varies from less than 10 ft to approximately 70 ft (Ebasco Services, Inc., et al., 1989a). The regional unconfined flow direction at RMA is to the North and Northwest. Deviations in these flow directions occur in the vicinity of the South Plants Manufacturing facility and in the lakes area. A ground-water mound underlying South Plants creates divergent radial flow away from the area. Ground-water flow beneath Ladora Lake and Lake Mary is to the West, whereas flow directions beneath Upper and Lower Derby Lakes are less well defined, but appear to have a

predominant westward component (SSAR, 1989, Figure SSA 1.5-4, Ebasco Services, Inc., et al., 1989b).

Water-level fluctuations in the unconfined aquifer at RMA are generally less than 2 ft, although fluctuations as large as 6 ft have been measured beneath South Plants (Ebasco Services, Inc., et al., 1989a). Present-day recharge to the unconfined flow system occurs as infiltration of precipitation, seepage from lakes, streams, canals and buried pipelines, and discharging flow from the Denver Formation. Discharge from the unconfined flow system occurs primarily as seepage into Upper Derby Lake and possibly into portions of First Creek (Ebasco Services, Inc., et al., 1989a).

2.3 Surface-Water Features

Surface water at RMA can be discussed in terms of both larger and smaller scale features. Five principle drainage basins occur within the RMA area. Lakes, ditches and creeks exist within those basins smaller subcatchments. The general characteristics of the drainage that exist on RMA are discussed in Section 2.3.1. Surface water features that exist within the principle drainage basins are discussed in Section 2.3.2.

The locations of the surface-water monitoring stations associated with each of the surface-water drainage basins at RMA are shown on Plate 1.3-1 (Surface-Water Quantity Monitoring Stations) and Plate 1.3-2 (Surface-Water Quality Sampling Locations). Table 2.3-1 lists the surface-water quantity monitoring stations located in each RMA drainage basin. Table 2.3-2 lists all surface-water quality sampling locations considered for use during Water Year 1989, within the major drainages. Section 3.0 discusses the monitoring procedures and equipment utilized in each drainage basin.

2.3.1 Drainage Basins

RMA lies within the South Platte River drainage basin. Surface-water on RMA flows within several smaller drainage basins that are tributaries to the South Platte. First Creek, Second Creek, Sand Creek, and Irondale Gulch drainage basins (Plate 2.3-1) contain defined flow channels that have a main direction of flow to the North and Northwest. The South Platte drainage (Plate 2.3-1) on RMA has no well defined main flow channel. The following discussion describes the principal drainage basins on RMA. Subcatchments of the South Platte Drainage Basin (Basin F and Basin A Drainages) are discussed in Section 2.3.2.3.

2.3.1.1 First Creek Drainage Basin. The First Creek Drainage Basin originates in Arapahoe County, Colorado, about 20 mi east of downtown Denver. The basin is approximately 26 mi long

Table 2.3-1 Monitoring Stations Used During FY89

Irondale Gulch Drainage Basin

North Uvalda (SW01001)

South Plants Ditch (SW01003)

Upper Derby Lake (SW01004)

Lower Derby Lake (SW01005)

Ladora Weir (SW02001)

Ladora Lake (SW02003)

Lake Mary (SW02004)

Peoria Interceptor (SW11001)

Havana Interceptor (SW11002)

Havana Pond (SW11003)

South Uvalda (SW12005)

Highline Lateral (SW12007)

First Creek Drainage Basin

South First Creek (SW08003)

Sewage Treatement Plant (SW24001)

North First Creek (SW24002)

First Creek Off-Post (SW37001)

South Platte Drainage Basin

Basin A (SW36001)

Sand Creek Drainage Basin

No Monitoring Stations

Second Creek Drainage Basin

No Monitoring Stations

Table 2.3-2 Sample Locations Considered During FY89

Irondale Gulch Drainage Basin	First Creek Drainage Basin
North Uvalda (SW01001)	First Creek Southern Boundary (SW08001)
South Plants Tower Pond (SW01002)	South First Creek (SW08003)
South Plants Ditch (SW01003)	Sewage Treatment Plant (SW24001)
Upper Derby Lake (SW01004)	North First Creek (SW24002)
Lower Derby Lake (SW01005)	North Bog (SW24003)
Ladora Weir (SW02001)	First Creek Northern Boundary (SW24004)
Sand Creek Lateral (SW02002)	North Plants (SW30001)
Ladora Lake (SW02003)	First Creek near North Plants (SW30002)
Lake Mary (SW02004)	First Creek Toxic Yard A (SW31001)
Sand Creek Lateral (SW02005)	First Creek Toxic Yard B (SW31002)
South Plants Steam Effluent (SW02006)	First Creek Off-Post (SW37001)
Uvalda Ditch (SW07001)	
Uvalda Ditch (SW07002)	South Platte Drainage Basin
Peoria Interceptor (SW11001)	Basin A (SW36001)
Havana Interceptor (SW11002)	
Havana Pond (SW11003)	Sand Creek Drainage Basin
Uvalda Ditch (SW12001)	Motor Pool (SW04001)
Uvalda Ditch (SW12002)	
Rod & Gun Club Pond (SW12003)	Second Creek Drainage Basin
Storm Sewer (SW12004)	No Sampling Locations
South Uvalda (SW12005)	
Highline Lateral (SW12007)	

SWAR-89.TBL

and varies from one to four mi in width (Figure 2.3.1). The basin drains approximately 27 sq mi upstream of RMA and approximately 12 sq mi on RMA. Land use upstream of the Arsenal is primarily agricultural (U.S. Army Corps of Engineers, 1983a). Soil infiltration capacities in the southeast portions of the First Creek Basin are low (0.06 - 2 in/hr) to moderate (0.6 - 6 in/hr), increase at the southeastern boundary of RMA, and are moderate within RMA boundaries (RCI, 1982). Off-post soil infiltration capacities upgradient of RMA are expected to change with the continued development associated with the proposed new Denver Airport and Green Valley Ranch. The topography of the First Creek Basin within RMA is gently undulating with low hills.

First Creek flows approximately 26 mi northwesterly from its source to its confluence with O'Brian Canal about 0.5 mi north of the northern boundary of RMA. This includes about 5.5 mi of channel on RMA. In dry years, the flow of First Creek on the Arsenal is continuous only during the spring and after major storms. The general persistence of flow along the creek is evidenced by well-developed hydrophytic and phreatophytic vegetation along much of its length (MKE, 1987). There are eight road or railroad crossings over First Creek within RMA. The original crossings consisted primarily of culverts with limited flow capacities beneath the roadways (U.S. Army Corps of Engineers, 1983a). Four roadway culvert systems with enlarged capacities have been built on First Creek since 1988 at crossings under F Street, December 7th Avenue, 6th Avenue and the North Boundary Containment System access road in Section 24. In late April 1989, 14 locations along First Creek on RMA were surveyed to determine thalweg slope- and surface-water elevations. Surface-water elevations were compared to ground-water elevations in nearby monitoring wells. An attempt was made to identify areas where influent or effluent conditions occurred along First Creek. Further discussion of ground-water interaction with First Creek is provided in Section 4.4. Thalweg elevations and 5 cross sections were measured at selected points on the creek and are shown in Figure 2.3-2.

Along the southern reach of First Creek, between survey points FC-1 and FC-8, the average thalweg slope is 29.87 ft/mi. Along First Creek's northern reach between survey points FC-9 and FC-13, the slope decreases to 29.20 ft/mi. This difference in slope is accompanied by a difference in channel geometry between the southern and northern reaches (Figure 2.3-1). Along the southern reach (in Sections 5 and 8) the creek is wide and in places has terraced banks. Upper bank-to-bank widths are up to 90 ft along some terraced stretches. Bank widths of the main channel are generally about 20 ft. Along outside channel bends, banks are steep and occasionally undercut. Bank material is composed of poorly consolidated silty sand. Slugged bank material occurs along some outer channel bends. Grassy vegetation stabilizes the gentler sloping channel banks. Maximum bank height is up to 10 ft. Intermittently located intrachannel bars and point bars indicate channel adjustment and sediment transport in this portion of First Creek.

An extensive marshy area exists along First Creek between December 7th Avenue and survey point FC-8. The marsh is several hundred feet wide in places, and is caused by three man-made earthen dams just south of survey point FC-8 that have been breached. Ponded water is still present in the vicinity of the earthen dam embankments (Figure 2.3-2).

Along the northern reach of First Creek on RMA, the channel has a smooth concave-upward shape and banks are generally less steep. Bank top widths range from 35 ft to 55 ft. Bank height ranges from approximately eight ft to four ft, generally decreasing in height towards the north end of this stretch. Bank material consists of silty sand and is generally stabilized by grassy vegetation.

Most of the course of First Creek on RMA is straight. Channel meandering is most common in Section 8 where First Creek comes on-post. Channel straightening was done in the northwest portion of Section 5 and on the east side of Section 24 following a major flood in 1973 (U.S. Army Corps of Engineers, 1983a). The channel capacity of the creek as it enters RMA is about 250 cubic feet per second (cfs) and downstream of the sewage treatment plant outfall at the north boundary it is about 300 cfs (RCI, 1982). Average monthly flows recorded during Water Year 1989 for the period of April to September at the new South First Creek gaging station (SW08003) ranged from 1.5 cfs in May to 0.11 cfs in September. Average monthly flows during Water Year 1989 for the period of April to September recorded at the new North First Creek gaging station (SW24002) ranged from 1.2 cfs in May and June to 0.00 cfs in July, August and September.

Storm sewer drainage is currently being routed into First Creek from the northeast portion of the Green Valley Ranch residential area. The storm runoff is collected in the vicinity of Nepal Street and the westernmost end of 48th Street. The area which directs flow into First Creek from Green Valley Ranch covers approximately 0.177 sq mi (Figure 2.3-1).

The Highline Lateral canal also has the potential to add runoff to First Creek. Highline Lateral crosses First Creek on the eastern side of Green Valley Ranch. An overflow diversion channel for the Highline Lateral is located at this intersection. The overflow channel can direct flow from the Highline Lateral canal into First Creek if the overflow level in Highline was surpassed. This occurred once during Water Year 1989.

As First Creek traverses RMA, several tributaries have the potential of contributing to its flow (Plate 2.3-1). The first well defined tributary, an old overflow for Upper Derby Lake, enters First Creek in Section 6. Under normal flow conditions, this tributary no longer carries water from Upper Derby Lake. First Creek then flows through three breached small detention or retention

dams in Section 31. Prior to being breached, the combined available storage behind these dams was approximately 150 ac-ft (U.S. Army Corps of Engineers, 1983a). The next tributaries join First Creek in the northwest corner of Section 31 and drain the old Toxic Storage Yard. The North Plants area is drained by a tributary which joins First Creek in the central-western portion of Section 30. The Sand Creek Lateral enters First Creek near the northeast corner of Section 25; however, the infrequent flows in the lateral have not normally reached the confluence in the past several years even though this did occur during Water Year 1989.

Effluent from the Sewage Treatment Plant enters First Creek in the northeast corner of Section 24. Just before First Creek crosses the north boundary, it intercepts a small channel which drains overflow from the North Bog. North Bog is a 2.7 acre (117,000 ft^2) body of water located in the northwest quarter of Section 24. During high flow events, water from First Creek flows into the bog. Since 1983 the North Bog has been used as a natural recharge for treated ground water from the North Boundary Containment System (Ebasco Services, Inc., 1988a).

In the fall of 1988, First Creek was diverted away from a stand of trees near the south-central border of Section 5. A new culvert was placed under 6th Avenue approximately 300 ft west of its old location. The creek was diverted in this area in order to reduce bank erosion and associated deterioration of the trees along this section of the creek. Preservation of trees along First Creek is important because they have become the seasonal roosting location of a large number of eagles at RMA. This construction also produced a small retention pond just south of 6th Avenue on First Creek. The primary purpose of this pond is to cultivate a habitat that can be used by eagles and waterfowl. The effect of surface-water ponding at this location on local ground-water conditions has not been determined at this time. There is a potential for creating an area of increased ground- [illegible] First Creek.

Four surface-water monitoring stations are located in the First Creek Drainage Basin (Table 2.3-1, Plate 1.3-1). Three of the stations that are located on First Creek monitor the quantity of surface-water flowing on to and off of RMA through First Creek. The fourth station monitors water discharging from the Sewage Treatment Plant. Eleven sampling locations have been designated within the First Creek Drainage Basin to monitor surface-water quality (Table 2.3-2, Plate 1.3-2).

2.3.1.2 Second Creek Drainage Basin. Only a small portion of Second Creek Basin is present in the northeast corner of RMA (Plate 2.3-1). The basin has a total drainage area of 20.6 sq mi, of which only 0.6 sq mi are within RMA. Upstream of RMA, Second Creek Basin is 9.1 mi in length. The width of the basin varies from 1 to nearly 3.5 mi, and the main channel length is 12.3 miles. The main stream channel crosses RMA at its very northeast corner, traversing less than 1,000 ft of

the Arsenal. Drainage is to the northwest (RCI, 1982). The soils of the Second Creek Basin have low infiltration capacities upstream of RMA, where land is primarily used for agriculture. Soils along Second Creek drainage on RMA have low to moderate infiltration capacities. The more incised and sinuous nature of the channels in this drainage, in comparison with that of First Creek, may be attributed to the lower infiltration rates exhibited by the soils in the Second Creek drainage (RCI, 1982). The portion of Section 20 that lies within Second Creek drainage has been used as a buffer zone for Arsenal operations.

No monitoring stations or sample locations are located in the Second Creek Drainage Basin, because of its limited extent of flow on RMA, and its peripheral location in a buffer zone,

2.3.1.3 Sand Creek Drainage Basin

Sand Creek drainage includes 2.2 sq mi in the southwest area of RMA. The lack of any major channelized flow has been attributed to the high infiltration capacities (2 - 20 in/hr) of the soils in this area (RCI, 1982). Many natural depressions in the basin intercept runoff, so that surface flow tends to be local. If an extreme precipitation event would occur, runoff could progress from one depression to another in a northwesterly direction, finally exiting on RMA's western boundary (RCI, 1982, Plate II).

The Sand Creek drainage is interrupted by the Stapleton Airport runways and drainage system, which extend into Section 10 adjacent to RMA. Runoff from the airport and the Sand Creek drainage is partially intercepted by the Havana Interceptor, which returns the flows to RMA within the Irondale Gulch Drainage Basin (Plate 2.3-1). A detailed hydrologic analysis of the drainage in this area was performed as part of the Stapleton Airport expansion studies (Wright-McLaughlin Engineers, 1969).

Land used upstream from RMA in Sand Creek Basin is dominated by Stapleton Airport and related facilities. Prior to construction of the north-south runway, Sections 9 and 10 and were used as buffer zones for Arsenal operations. A U.S. Post Office installation and is located in Section 9.

Monitoring stations are not present in the Sand Creek Drainage Basin on RMA. Surface-water impoundments do not exist nor do any channels exhibiting flow into or exiting this drainage within RMA. One sample location is in a ditch that directs flow toward the north from the motor pool area is in this drainage basin (Table 2.3-2, Plate 1.3-2).

2.3.1.4 South Platte Drainage Basin. Approximately six sq mi in the northwest corner of RMA drain toward the South Platte River. This subcatchment is bounded by the Irondale Gulch drainage to the Southwest, the Sand Creek Lateral to the East and Southeast, and First Creek to the Northeast (Plate 2.3-1). The South Platte drainage does not contain a distinct channel and is characterized by a large number of natural depressions similar to Sand Creek Basin. Three subordinate drainages, Basin A, Basin F, and the Sand Creek Lateral Sub-Drainage have been delineated within the South Platte Drainage Basin. Characteristics of these smaller sub-drainages are discussed in Sections 2.3.2.1 (Diversion Channels and Ditches) and Section 2.3.2.3 (Collection Basins). Soil infiltration capacities (2 - 20 in/hr) are high in the central and southwest portion of the subcatchment, moderate (0.6 - 6 in/hr) in the west, southeast and north-central areas, and low (0.06 - 2 in/hr) in the north-northeast sections where bedrock is near the surface (RCI, 1982). Due to the low infiltration rates, more overland flow is expected in the north-northeast area of this subcatchment. The flow would be to the north and west boundaries of RMA.

Only one surface-water quantity monitoring station is located within the South Platte Drainage Basin. It is located near a drainage pipe in the Basin A Drainage. At this location both surface-water quantity and surface-water quality are monitored (Tables 2.3-1 and 2.3-2, Plates 1.3-1 and 1.3-2).

2.3.1.5 Irondale Gulch Drainage Basin. The Irondale Gulch Drainage Basin originates at the intersection of Interstate 70 and East Colfax Avenue. It drains 11.5 sq mi upstream of RMA and 6.5 sq mi of RMA. Flow is to the Northwest. The drainage area consists of undulating topography with low rolling hills. Vegetation is mainly grasses, with some scattered trees along the lakes and channels and in some low areas (U.S. Army Corps of Engineers, 1983d).

Four lakes and several other impoundments are located in the Irondale Gulch Basin on RMA. The Havana and Peoria Interceptors, Uvalda Street Interceptor and Highline Lateral all flow from south of RMA to the lakes (Plate 2.3-1). Upstream drainage patterns have been modified by the construction of subdivisions, channelizations and storm drains. Upstream development is composed of light industrial development, urban residential development, open range land, and a portion of Stapleton Airport. Urban development covered 32 percent of the basin in 1983 and was expected to increase (U.S. Army Corps of Engineers, 1983a).

Soil infiltration rates are high throughout most of the Irondale Gulch Drainage Basin except southeast of the lakes on RMA. Infiltration rates are reported to be moderate in this area (RCI, 1982). Natural drainage channelization is poorly defined or lacking over most of Irondale Gulch Basin on RMA due in part to the moderate-to-high soil infiltration rates.

Superimposed on these natural drainage basins are man-made structures that have modified the surface-water system. These structures include diversion ditches, major lakes, impoundments developed to retain storm runoff, as well as many culverts, sewers, and other control structures. The Irondale Gulch Drainage Basin contains the majority of the surface-water monitoring sites operated on RMA with 12 monitoring stations (Table 2.3-1, Plate 1.3-1) and 22 potential sampling locations (Table 2.3-2, Plate 1.3-2). The monitoring and sampling stations are concentrated in the southeastern portion of this drainage. These sites are associated with surface-water flows entering RMA from the southern boundary and the South Plants Lakes area.

2.3.2 Other Surface-Water Features

The following sections discuss characteristics and development history of the principal surface-water features that direct or constrict flow within the major drainage basins on RMA.

2.3.2.1 Diversion Channels and Ditches. Flows within the natural drainage basins on RMA have been greatly modified through the construction of a number of diversions (laterals) and drainage channels (interceptors). The principal channels on RMA -- Highline Lateral, Uvalda Interceptor, Peoria Interceptor, and Havana Interceptor -- enter along its southern border and carry water to the lakes near South Plants or Havana Pond.

Highline Lateral enters RMA near the southwest corner of Section 8 and flows northwest to a diversion box located in the southeast corner of Section 1. At this structure flow can be directed north to Upper Derby Lake or merged with the Uvalda Interceptor and emptied into Lower Derby Lake (Plate 2.3-1). Since 1942, the Highline Lateral has been used as an intake canal for water delivery to the South Plants Lakes from the Cheesman Reservoir. Flow is artificially controlled, with intake based on seasonal availability and water rights controlled by RMA. Approximately 1.7 mi of Highline Lateral lie on RMA. The lateral has an average bottom width of 8 ft and an average channel depth of 4 ft. Discharge capacity is calculated to be 75 cfs (U.S. Army Corps of Engineers, [illegible]). During Water Year 1989 when in use, maximum average daily discharges ranged from 22.0 cfs in May to 7.2 cfs in August.

Uvalda Interceptor enters RMA near the center of the southern border of Section 12 and flows north about 1.2 mi to a diversion structure located in the southeast corner of Section 1. From this point flow can be directed either to Upper Derby Lake or to Lower Derby Lake, and may be merged with flow from Highline Lateral. Uvalda Interceptor was completed in 1967 to channel runoff from the Montbello subdivision, adjacent commercial industrial areas, and rangeland south of RMA. The

drainage basin area for the Uvalda Interceptor is approximately 7.8 sq mi, of which 4.12 sq mi is residential, with an associated storm sewer system. Normally, the Uvalda Interceptor receives storm runoff from the northern portion of Montbello and the undeveloped area directly west of Chambers Road. Storm runoff from the Green Valley Ranch residential area drains into Irondale Gulch drainage via Uvalda Interceptor during a significant rainfall event. The storm sewer discharge area for Green Valley Ranch is a collection basin located west of the development. Overflow from this basin could flow into the Montbello sewer system and eventually into the Uvalda Interceptor (Figure 2.3-3). This channel has a discharge capacity of 1,200 cfs at the south RMA boundary and 600 cfs near 6th Avenue (U.S. Army Corps of Engineers, 1983a). The average channel bottom width is 7 ft, and the average depth of the channel is 8 ft (Larsh, 1969). Mean monthly flows recorded during Water Year 1989 at the South Uvalda gaging station (SW12005) ranged from 1.7 cfs in July to 0.31 cfs in March.

The Havana Interceptor drains industrial and residential areas south of RMA, flows to the north-northeast across Section 11, and terminates in the Havana Pond. Havana Interceptor drains land with commercial and light industrial development, residential housing and some rangeland (RCI, 1982). Storm runoff from Stapleton Airport is also included in the drainage received by the Havana Interceptor (Hunter/ESE, 1985). Havana Interceptor is a lined concrete canal as it enters RMA. The drainage basin for the Havana Interceptor is about 5.22 sq mi, of which 2.6 sq mi is storm sewer drainage. This drainage receives runoff from the southern portion of Montbello and the industrial complex on the south side of the RMA. The drainage subbasin extends in a narrow zone east to approximately Sky Ranch Airport and is bounded on the south by Interstate 70 (Figure 2.3-3). Mean monthly flows recorded during Water Year 1989 recorded at the Havana Interceptor gaging station (SW11002) ranged from 2.98 cfs in July to 0.26 cfs in November.

Peoria Interceptor enters RMA along the southern edge of Section 11 and flows about 0.3 mi before joining Havana Interceptor and emptying into Havana Pond. The Peoria Interceptor drains the northern portion of the industrial complex located on the south side of the Arsenal. Storm sewer runoff from a small portion of western Montbello is also directed towards the Peoria Interceptor. Mean monthly flows recorded during Water Year 1989 at the Peoria Interceptor gaging station (SW11001) ranged from 1.21 cfs in June to 0.19 cfs in November. The drainage basin entails approximately .644 sq mi, which is almost entirely urban storm sewer runoff (Figure 2.3-3). Construction of the interceptor was completed in 1980 (U.S. EPA, 1988). Havana Pond contains 5 ac-ft of water covering 5 acres during normal pool storage. In the past, water levels were kept low to allow for additional storage capacity during flood events. The pond originally could hold 79 ac-ft of water covering 22 acres if filled to the crest of the embankment (U.S. Army Corp of Engineers, 1983d). Two separate mechanisms are in place that can be used to discharge water from

Havana Pond to Sand Creek Lateral. A valve-controlled sluice gate on a 18-inch pipe is used to regulate flow manually out of the pond. In the fall of 1988, a 56 ft long, 12 ft wide concrete spillway was installed to allow overflow during a 10 year flood event. At overflow the pond would be holding 30 ac-ft of water.

Sand Creek Lateral enters RMA along the western edge of Section 11 just north of Havana Pond. A short ditch connects the spillway and a valve-controlled discharge point at the north end of the pond to Sand Creek Lateral. This lateral originally was connected to Sand Creek, which flows about 1.2 mi southwest of the Arsenal, and was used to carry irrigation water to farms on land now occupied by RMA (MKE, 1987). Construction of the northern extension of Stapleton Airport filled in a portion of the lateral and disconnected it from Sand Creek. The lateral leaves Irondale Gulch drainage in the southern portion of Section 35, flows northeast through the South Platte drainage, and terminates at First Creek in the First Creek drainage. The Sand Creek Lateral intercepts surface flow within the Irondale Gulch and South Platte drainages and is therefore considered to have a catchment area (Plate 2.3-1).

Normally, water from Havana Pond is released to Sand Creek Lateral only after large storm events. The sluice gate used to regulate flow out of the pond to the lateral is opened when the water level on the staff gage measures 6 feet. The gate is closed when the staff reading declines to 4 ft (James Green, Chief Facility Engineer RMA, personal communication, 1989). A staff gage reading of 6 ft corresponds to 121.81 ac-ft of water being held in the pond, while 4 ft on the staff gage means that 59.84 ac-ft of water is present in Havana Pond (Ebasco Services, Inc., et al., 1989a). Flow in Sand Creek Lateral could also originate from the South Plants lakes (Upper Derby Lake and Lower Derby Lake) if water was released into the lateral from Lower Derby Lake at the Ladora Weir rather than being diverted into Ladora Lake. Surface drainage and runoff from the southwestern area of South Plants is intercepted by Sand Creek Lateral downgradient of the diversion structure. Water pumped from three wells located in Section 4, which is used to supplement water in the South Plants lakes, can also be discharged into Sand Creek Lateral.

Within the South Platte drainage, a channel is located near the eastern boundary of the catchment. The channel originates near the Lime Settling Ponds in Section 36. Water within this channel flows under Sand Creek Lateral and into the South Platte drainage.

The Sand Creek Lateral catchment within the South Platte drainage also contains a reservoir in the eastern side of Section 35 which usually is dry. The reservoir was designed and constructed as a basin to receive caustic waste from the South Plants area, although it was never used for this purpose. The caustic waste basin does not have a formal outlet. Consequently, it is probable that no

surface flows escape the caustic waste basin, so that all precipitation is either stored, evaporated, transpired or infiltrated. Flow in the Sand Creek Lateral can be diverted to Basin C, and was so diverted from 1953 to 1956. Aqueous waste overflows from Basin B were also diverted to Sand Creek Lateral during that period.

2.3.2.2 Lakes and Ponds. Four lakes and two ponds lie within the Irondale Gulch Drainage Basin at RMA (Plate 2.3-1). These bodies of water are important in that they are a significant component in the ground-water/surface-water interaction occurring at the Arsenal. Further discussion concerning the hydraulic communication occurring between these surface-water bodies and the ground-water flow system at RMA is provided in Section 4.4. Three of the larger impoundments (Upper Derby Lake, Lower Derby Lake and Ladora Lake) were used as part of the process water system from 1942 until 1964. These lakes are connected to a number of diversion channels used to supply or divert water from the lakes. The lakes acted as a cooling system that dissipated heat from water used in the manufacturing processes in South Plants and also provided water for fire protection.

Water was pumped from the northwestern (lower) end of Ladora Lake, circulated through various South Plants manufacturing facilities, and then discharged into Upper Derby Lake via an open return water ditch (D12) located at the north end of the lake (Figure 2.3-4). The lakes formed a natural cascading flow system, with water being cooled as it moved from Upper to Lower Derby and finally into Ladora Lake. In 1963, the return-water ditch was rerouted to bypass Upper Derby Lake and to drain directly into Lower Derby Lake (MKE, 1987). In 1964, the portion of the lakes system serving the eastern section of South Plants was converted to a closed-loop system using a cooling tower (Ebasco Services, Inc., 1988). The South Plants lakes were not used to cool the manufacturing process after 1964, but they did continue if necessary to serve as a cooling system for the Arsenal's steam plant and to replace water lost from the closed-loop system (MKE, 1987).

The eastern portion of the process water loop using the cooling tower and associated sedimentation pond has not been in operation since 1976. An elevated storage tower is kept full to supply water when needed (Stearns-Rogers Engineering, personal communication, 1989). Presently, process water used in the steam plant and for irrigation is taken from Ladora Lake at a pump station located near its north end. Return water from the steam plant is discharged into a north-south oriented ditch located south of the facility (D-3, Figure 2.3-4), which in turn connects to a series of ditches leading to Sand Creek Lateral.

Further discussion of the process water system is provided in Section 2.4. The remainder of this discussion is directed to the history of the individual lakes and ponds and their physical characteristics.

2.3.2.2.1 Upper Derby Lake. - Upper Derby lake is the uppermost lake that was used in the process water cooling system. The main part of the lake is located in the southwest quarter of Section 1. The eastern extension of the lake (Eastern Upper Derby Lake) is located to the East across "E" Street (Plate 2.3-1). Upper Derby Lake was created by constructing a dam east of Lower Derby Lake to increase the volume of water in storage for the process water system. Upper Derby Lake was built shortly after Lower Derby and originally was lined with clay to reduce seepage. Between 1964 and 1965 the lake bottom was excavated to remove contaminated sediments. Between 1980 and 1982, the lake was drained and natural revegetation occurred. Since that time it has been used for flood control (Knaus, 1982). Upper Derby Lake can receive inflow both from Highline Lateral and the Uvalda Interceptor. The surface area of the lake at full operating capacity is 83 acres, with a storage capacity of 460 ac-ft of water (Graff & Reilly, 1943).

Eastern Upper Derby Lake has a clay-lined bottom and covers about 15 acres. The Upper Derby Lake Overflow ditch exits from the north edge of the lake and flows northeast towards First Creek. In the spring and early summer months, the lake can be filled from surface inflow through a culvert from Upper Derby Lake. During the late summer, fall and winter months when surface runoff is low, the lake is marshy or dry (Ebasco Services, Inc., 1987b).

2.3.2.2.2 Lower Derby Lake. - Lower Derby Lake is located in south-central Section 1 between Upper Derby Lake and Ladora Lake (Plate 2.3-1). The lake is visible on a July 16, 1937 air photograph, but is smaller in size. The lake was originally used as an irrigation reservoir at the time RMA was established. In 1942, the lake's storage capacity was increased when the Army modified the existing earthen dam by raising the crest 3 ft, regrading the side slopes, and installing a new drain line (U.S. Army Chemical Warfare Service, 1945). The lake was originally lined with clay to reduce water seepage (Gatlin, 1964, cited in Ebasco Services, Inc., 1987c). In 1963, the easternmost return ditches (D12, Figure 2.3-4) ceased being used. Instead of flowing to Upper Derby Lake, drainage from the South Plants area was rerouted to Lower Derby Lake through ditches D15 and D15A (Figure 2.3-4) (Williams, 1963, cited in Ebasco Services, Inc., 1987c). In 1964, a closed loop cooling tower system was installed, which effectively removed the lakes from the process water system (Culley, 1971, cited in Ebasco Services, Inc., 1987c), and a ditch (D15B, Figure 2.3-4) was constructed at the northwestern end of Lower Derby Lake to connect with a pipe and drain into Ladora Lake (Donnelly, 1983, cited in Ebasco Services, Inc. 1987c). This diversion controlled outflow from Lower Derby Lake. Between 1964 and 1965, Lower Derby Lake was excavated to

remove contaminated sediment (Kenny, 1965, cited in Ebasco Services, Inc. 1987c). Up to 12 in of sediment were removed from the lake bottom and disposed of in Sections 11 and 12 (Wingfield, 1977, cited in Ebasco Services, Inc. 1987c).

Because of flooding that occurred in the Irondale Gulch through Lower Derby Lake in May 1973, an emergency overflow ditch (D5, Figure 2.3-4) was constructed south of the lake to carry overflow water to the Rod and Gun Club Pond.

Lower Derby Lake can receive inflow from both the Highline Lateral and the Uvalda Interceptor. As of 1982, Lower Derby Lake stored water that is used to maintain the water level in Ladora Lake. Lower Derby Lake is currently used for recreational fishing under a catch-and-release program (Ebasco Services, Inc., 1987c). The normal pool storage volume of the lake is 550 ac-ft with a surface area of 73 acres (U.S. Army Corps of Engineers, 1987).

2.3.2.2.3 Ladora Lake. - Ladora Lake, located in the central and south-central portion of Section 3 (Plate 2.3-1), was constructed for use in irrigation by farmers prior to construction of RMA (Donnelly, 1986, cited by Ebasco Services, Inc. 1987c). In 1942 the lake was enlarged to increase its storage capacity for water used in the process water system. At this time the bottom was sealed with clay to reduce water seepage (Gatlin, 1960, cited by Ebasco Services, Inc., 1987c), and the process water pumphouse located adjacent to Ladora Lake was constructed (Ebasco Services, Inc., 1987c).

A number of modifications and repairs have been undertaken at Ladora Lake since 1942. The inlet ditch at the eastern end of the lake was deepened in 1957 (Donnelly, 1963, cited in Ebasco Services, Inc., 1987c). In 1963, ditch D15B was constructed along the northwestern edge of Lower Derby Lake to carry return cooling water through a pipe along the bottom of Lower Derby Lake and into the sluice box located between Lower Derby Lake and Ladora Lake (Donnelly, 1963, cited in Ebasco Services, Inc., 1987c). The lake was drained during 1964 and 1965, and the upper 6 to 12 in of the lake bottom sediments were removed and disposed of in the north-central portion of Section 11 (Ebasco Services, Inc., 1987c). During the 1973 flood, water flowed over and damaged Ladora Lake's undefined western spillway. After 1975, overflows from Ladora Lake could no longer enter Lake Mary. A ditch (D6) was constructed which diverted overflow around the south end of Lake Mary, directing it north along the east side of "C" Street, and then to the West under "C" Street to an overflow basin in the eastern portion of Section 3 (Figure 2.3-4). This ditch and a new spillway were reconstructed during the summer of 1989. The normal pool storage volume of Ladora Lake is 400 ac-ft, with a surface area at that volume of 48 acres (U.S. Army Corps of Engineers, 1987). Average water depth is estimated to be 5.6 ft (MKE, 1987).

2.3.2.2.4 Lake Mary. - In 1960 the swampy area directly west of Ladora Lake in Section 2 (Plate 2.3-1) was excavated and a berm was constructed to create a small 7 acre lake (Donnelly, 1986, cited in Ebasco Services, Inc. 1987c). Additional water was added and this early version of Lake Mary was stocked with fish. Several years later, parallel earthen mounds were constructed to partition the eastern portion of the lake into three areas for use in minnow-rearing. Shallow sections of the lake were dredged and tree stumps removed during 1967 (Mack, 1967, cited in Ebasco Services, Inc. 1987c). During 1974, Lake Mary was drained, enlarged slightly, and deepened to an average depth of 15 ft to enhance the quality of the water for the fish (Mullan, 1975; Schmidt, 1975; cited in Ebasco Services, Inc. 1987c). During this renovation, spillway ditch D6 was constructed to direct overflow from Ladora Lake around the southern edge of Lake Mary. Lake Mary was refilled with water from a deep well instead of from the industrial lakes to prevent possible contamination (MKE, 1987). Lake Mary can receive a regulated water supply from several sources: water pumped from three alluvial wells located in Section 4, water pumped from Ladora Lake and potable water discharged from the one million gallon storage tank. A 4-in steel siphon pipe located between Ladora Lake and Lake Mary was inoperative throughout 1988 and 1989. This siphon is expected to be reopened and made functional sometime in 1989 in order to supply water from Ladora Lake to Lake Mary (James Green, Chief Facilities Engineer, RMA, personal communication, 1989). Lake Mary occupies nine acres at a normal pool storage volume (spillway crest) of 60 ac-ft (U.S. Army Corps of Engineers, 1983b).

2.3.2.2.5 Rod and Gun Club Pond. - The Rod and Gun Club Pond located in the north-central part of Section 12 occurs in a natural topographic depression south of Lower Derby Lake (Plate 2.3-1). The area occupied by the pond may have been excavated between 1965 and 1971, as indicated by aerial photographs (MKE, 1987). The shallow ditch that connects the Rod and Gun Club Pond to Lower Derby Lake was constructed during the May 1973 flood to carry overflow from the lake. During 1977, water was pumped from Lower Derby Lake to the Rod and Gun Club Pond to maintain the pond's water level (Rocky Mountain Fisheries Consultants, Inc., 1978, cited in MKE, 1987), but has lost water since that time. The pond receives runoff from a small catchment. When water levels are high enough, overflow from Lower Derby Lake can replenish the water in the pond. The Rod and Gun Club Pond can also receive overflow from the Uvalda Interceptor when the stage in the Uvalda Interceptor is high enough for water to flow through a low area or cut in its bank. This overflow water from the interceptor moves across a field in an undefined channel before reaching the Rod and Gun Club Pond. The surface area of the pond when full has been estimated at approximately 19.3 acres (Ebasco Services, Inc. 1986; cited in MKE 1987). This includes the marshy area around the pond. The actual pond covers about 4.9 acres and has a volume of less than 15 ac-ft.

2.3.2.3 Collection Basins. Six basins used for the retention of process wastes, waste water, or storm runoff were constructed on RMA within the South Platte Drainage Basin (Plate 2.3-1). These basins are natural topographic depressions which have been supplemented by berms and other structures. The topographic depressions associated with the basins have small catchment areas.

The Basin A subcatchment has a total area of approximately 240 acres in Sections 1 and 36. The subcatchment includes the Basin A disposal area and portions of the South Plants industrial complex. The Basin A disposal area was originally a natural depression that was modified by embankments to provide greater storage for liquid process wastes (U.S. Army Chemical Warfare Service, 1945). In 1952 the impoundment dike was raised 5 ft to handle additional waste to be generated by the North Plants operations (Moloney, 1982). In 1956, the contents of Basin A were transferred to Basin F (PMCDIR, 1977).

The subcatchment receives runoff that is transported from the northern part of the South Plants industrial complex through the storm water drainage system under December 7th Avenue (U.S. Army Corps of Engineers, 19[illegible]). Most runoff within this subcatchment collects in low areas and causes local ponding in the Basin A area, where it either infiltrates, transpires, evaporates or remains in storage.

Surface-water discharge from the subcatchment occurs primarily along the small drainage on the northwest portion of Section 36, referred to as the Basin A ditch. Flow is from Basin A to Basin B, and subsequently out to Basins C, D and E (Blackwell, 1973). Runoff is therefore contained within the basins and either evaporates or infiltrates into the soil. Basin A subcatchment runoff does not directly contribute to any of the major surface-water drainages at RMA (RCI, 1982).

Basin B is located in the northeast corner of Section 35. The basin covers 1.77 acres and is a modified natural topographic depression. A series of ditches connecting Basin A to Basins B, D and E were constructed in 1946. At that time, a culvert was built under Sand Creek Lateral in the ditch flowing out of Basin B to prevent overflow water from entering the Sand Creek Lateral. The purpose of this ditch system was to provide a controlled pathway for outflow in the event that the Basin A dam failed, and also to provide additional storage for liquid waste overflows from Basin A (U.S. Army Chemical Warfare Service, 1946). A new Basin A runoff ditch was constructed in 1957 and was used until 1964. Drainage through this ditch can enter Basin B from the Southeast. However Basin B was observed to be dry in 1985, and has been noted as containing only a small marsh with limited catchment area since 1986 (CAPS, 1986).

Basin C is an unlined basin that was constructed in 1953 (Hunter/ESE, 1987) in a natural depression in the south-central portion of Section 26. The basin was designed as the primary overflow

containment basin for Basin A wastes prior to construction of Basin F. Basin C covers approximately 78 acres when it is at a spillway crest storage volume of 620 ac-ft (U.S. Army Corps of Engineers, 1983c). In 1953, as part of the project for the construction of Basin C, the Army closed the culvert under the Sand Creek Lateral adjacent to the outfall ditch from Basin B, and modified this outfall to divert waste fluids overflowing the Basin into the Sand Creek Lateral and ultimately into Basin C via a connecting ditch installed at headgate No. 41 (U.S. Army Corps of Engineers, 1953). Concrete weirs and unlined ditches were also installed to connect Basins C, D and E (Hunter/ESE, 1987). From late 1953 until the construction of Basin F in 1956, excess waste fluids from Basins A and B flowed via this pathway, first to Basin C, and then to Basins D and E (U.S. Army Corps of Engineers, 1953). It is not known when the culvert under the Sand Creek Lateral was reopened after 1956. All waste fluid flowing into the basin was consequently derived from overflow from Basins A and B or from surface drainage ditches in the South Plants that led into the Sand Creek Lateral (Hunter/ESE, 1987). The basin was used for two months during the spring of 1957 while the liner in Basin F was undergoing repairs. In 1962, the Army installed a pump, a diversion box at the inlet to Sand Creek lateral near the basin's north embankment, and a series of ditches. The ditches led to the northern portions of the Sand Creek Lateral and were used to retain and transport fresh water to the TX wheat fields in Sections 23 and 24. Actual water storage in the basin did not begin until 1965 (RMA, 1962 and 1963, as cited in Hunter/ESE 1987). The basin was observed to be dry in 1986 (CAPS, 1986).

Basin D is located in south-central Section 26, south of Basin F and southwest of Basin C, and covers approximately 20 acres. A ditch directs overflow from the basin west into Basin E.

Basin E covers 29.4 acres in the southwest potion of Section 26, southwest of Basin F and west of Basin D. The storage volume and drainage area of the basin are unknown. Flow is received from Basin D. There is no outflow. By 1980, all the fluids in Basin E had evaporated or infiltrated (Hunter/ESE, 1986b). Standing water presently occurs in the basin.

The Basin F subcatchment was located just north of the Sand Creek Lateral drainage, west of the First Creek drainage, and within the South Platte drainage area. The basin was removed and the area was recontoured during the Interim Response Action that was completed in 1989. The topography of the surrounding area is that of gently undulating grassland and with no well- defined drainage patterns. Soil infiltration rates are low to moderate in this area (RCI, 1982). The basin was a natural topographic depression that was modified to contain liquid wastes generated at RMA. Basin F was lined with 3/8 in of blown asphalt to prevent seepage when originally constructed (Hunter/ESE, 1988c).

Basin F was a primary disposal site for liquid and chemical wastes at RMA from 1956 to 1981. The basin was roughly oval in shape, 2,900 ft wide at the north end and 1,600 ft wide at the south end. The total area was 92.7 acres and could formerly contain a maximum volume of 746 ac-ft (Hunter/ESE, 1988c).

Basin F was considered to be a capture system (RCI, 1982). Surface water that was contained in the basin remained in storage, or evaporated. Recent construction has altered the former drainage characteristics of this area. Although nearby Basins C, D and E have revegetated, Basin F contained wastes until the Interim Response Action was initiated in 1988. (Ebasco Services, Inc., et al., 1989a). As part of the Interim Response Action, Basin F was also revegetated and the area was recontoured. The basin no longer contains contaminated liquid waste. A clay cap has been applied to the floor of the basin and also to the top of the waste pile.

2.4 Sewer System

RMA sewer system components that affect surface water at RMA are the process water system and the sanitary sewer system. The process water system is comprised of three subsystems: the lakes system, the South Plants closed-loop system, and the North Plants closed-loop system. The lakes system formerly supplied process water for the South Plants manufacturing processes, the administration area, and housing areas for fire protection. Water was pumped out of Ladora Lake and was distributed to the various facilities. Water used in the South Plants area for cooling purposes was returned to the Derby Lakes. In 1964 a closed-loop system was created for industrial activities occurring in the eastern South Plants area (Ebasco Services, Inc., August, 1988).

The South Plants closed-loop system used a cooling tower and storage reservoir, a pump station and an elevated storage tank. Cooling tower blowdown water was discharged to a sedimentation pond located immediately south of the cooling tower. After treatment by sedimentation, the water was pumped back into the closed-loop system. Return water did not enter the lakes system; however, make-up water was obtained from the lakes system.

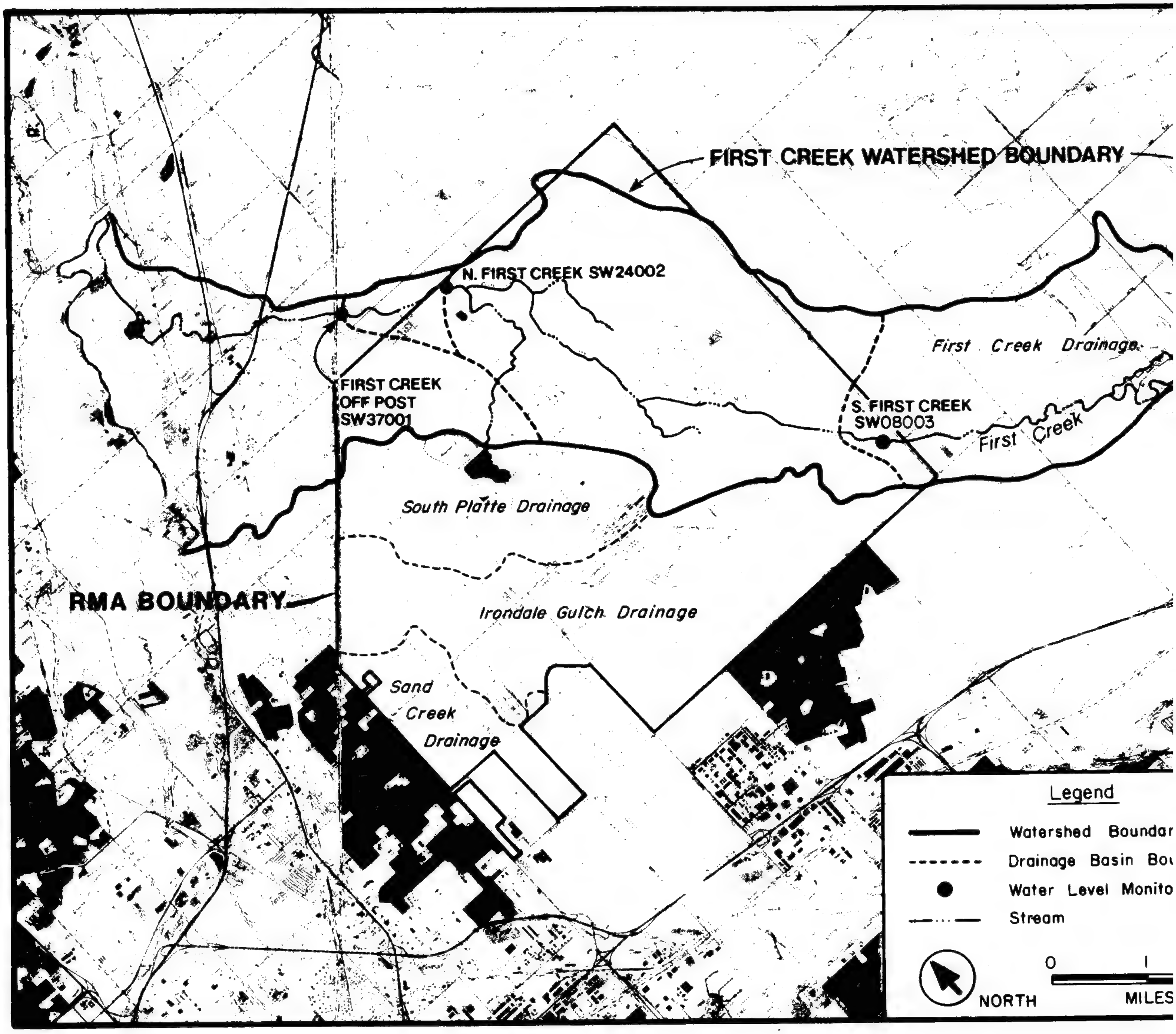
In 1975 the closed-loop system using the cooling tower and sedimentation pond ceased operation (Stearns-Rogers Engineering, personal communication, 1989). At present, the only activities in South Plants that require process water from the lakes system are those in the power plant. The process water system also provides water for irrigation (lawn watering), and back-up water for fire protection. Water is withdrawn from Ladora Lake using a 75 horsepower pump operating at 30 gallons/minute. Cooling water from the power plant is discharged into a small ditch located south of the power plant (Figure 2.3-4). This ditch connects to a series of east-west oriented ditches that discharge into Sand Creek Lateral.

The process water distribution system of the lakes system was extended to the North Plants manufacturing complex in 1952 to provide fire protection and make-up water for the North Plants closed-loop system. The North Plants closed-loop system used a cooling tower and an elevated storage tank with an attached pump station. Process return water from the North Plants complex was not returned to the lakes system. Cooling tower blowdown water was discharged to the North Plants storm drainage system. This drainage network consisted of a ditch system that captured surface runoff, sewer storm drainage, and process-water discharge, and then directed it from the southern North Plants area to First Creek.

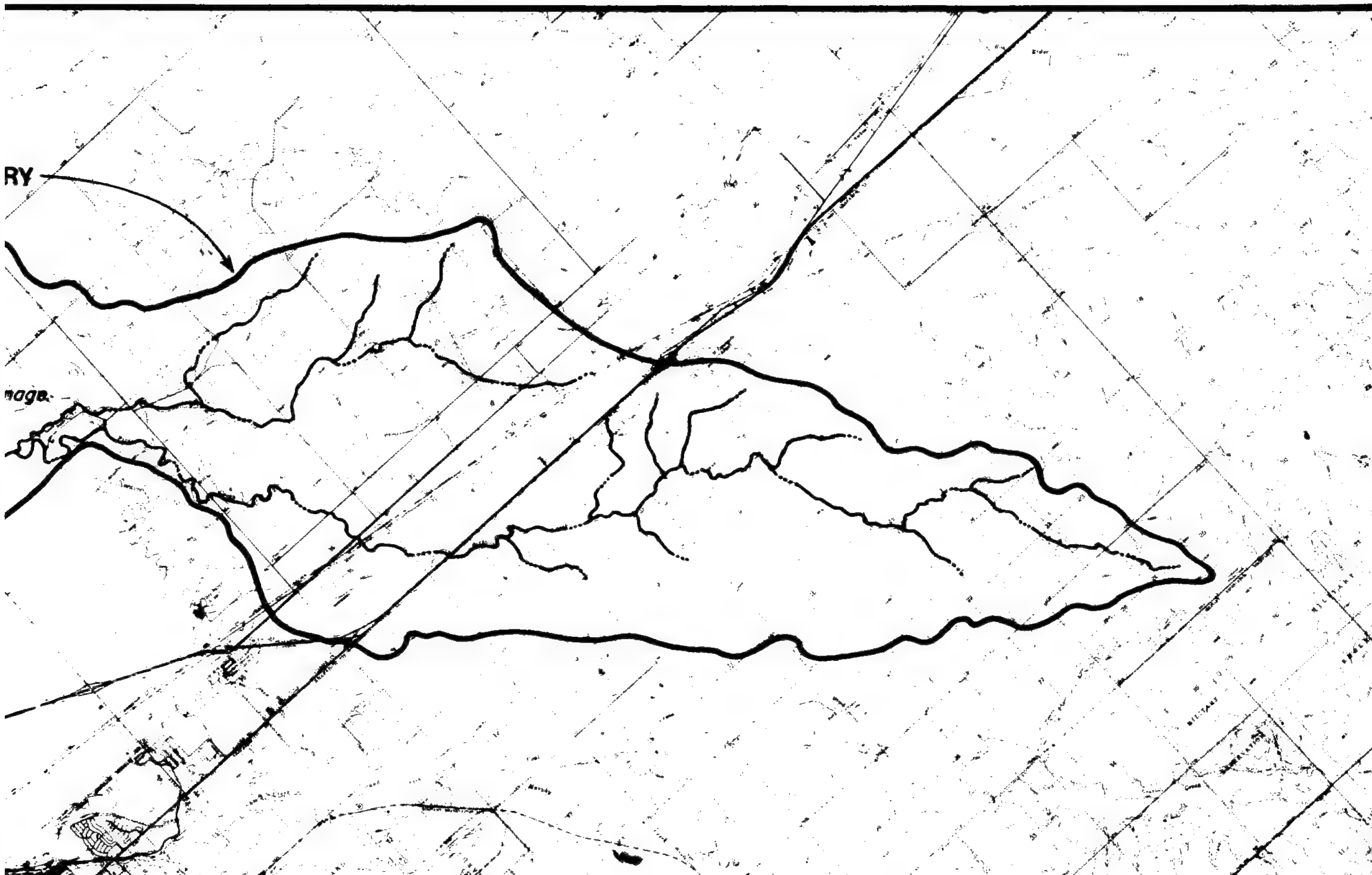
Circa 1980 the drainage network was modified to direct some surface-water runoff in the southeastern portion of the North Plants to a ditch that flowed north along the east margin of the facilities (USEPA, 1982). The ditch connecting to First Creek was retained but modified. Ditch D 26B then had a starting point along the eastern fence and perimeter road (Figure 2.3-4). Ditch D 26A remained connected to the storm sewer drainage network located inside the southern North Plants area. At present, no process water is discharged from North Plants, and the ditches in the area carry only storm sewer effluent and surface-water runoff.

Make-up water for the lakes system is normally supplied by irrigation water from the Highline Lateral or storm water from the Uvalda Interceptor. Water can also be supplied from wells in Section 4, or from the potable water system that is connected to the City of Denver water system for fire protection and irrigation emergency uses. The process water system is designed to be operated in association with the potable water system, so that in the event of breakdown or water supply problems, one system can substitute for the other (Ebasco Services, Inc., 1988c).

The other element of the sewer system at RMA affecting surface-water flow is the sanitary sewer system. The sanitary sewer Interceptor Line originates near the north boundary of Section 1 in South Plants and terminates at the Sewage Treatment Plant in Section 24 (Plate 2.3-1). The sanitary sewer Interceptor Line collects and transmits domestic wastewater from the administration and railroad areas, the North Plants complex, and the South Plants manufacturing area (Ebasco Services, Inc., et al., 1988b). At the Sewage Treatment Plant, wastewater is pre-filtered through a sand and gravel sequence before it is treated in a granulated active carbon and in-line ozonation system (Ebasco Services, Inc., et al., 1987a). Effluent is discharged into a ditch that is connected to First Creek in Section 24. Discharge from the facility is recorded continuously by a totalizing flow meter. Recorded yearly average flows from the facility during the Water Year 1989 monitoring program measured 9.99 gallons per minute.



FIRST CREEK WATERSHED BOUNDARY
N. FIRST CREEK SW24002
FIRST CREEK
OFF POST
SW37001
S. FIRST CREEK
SW08003
First Creek Drainage
First Creek
South Platte Drainage
RMA BOUNDARY
Irondale Gulch Drainage
Sand
Creek
Drainage
Legend
Watershed Boundar
Drainage Basin Bou
Water Level Monito
Stream
0
1
NORTH
MILES



d

Boundary

asin Boundary

l Monitoring Station

1 2

MILES

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Commerce City, Colorado

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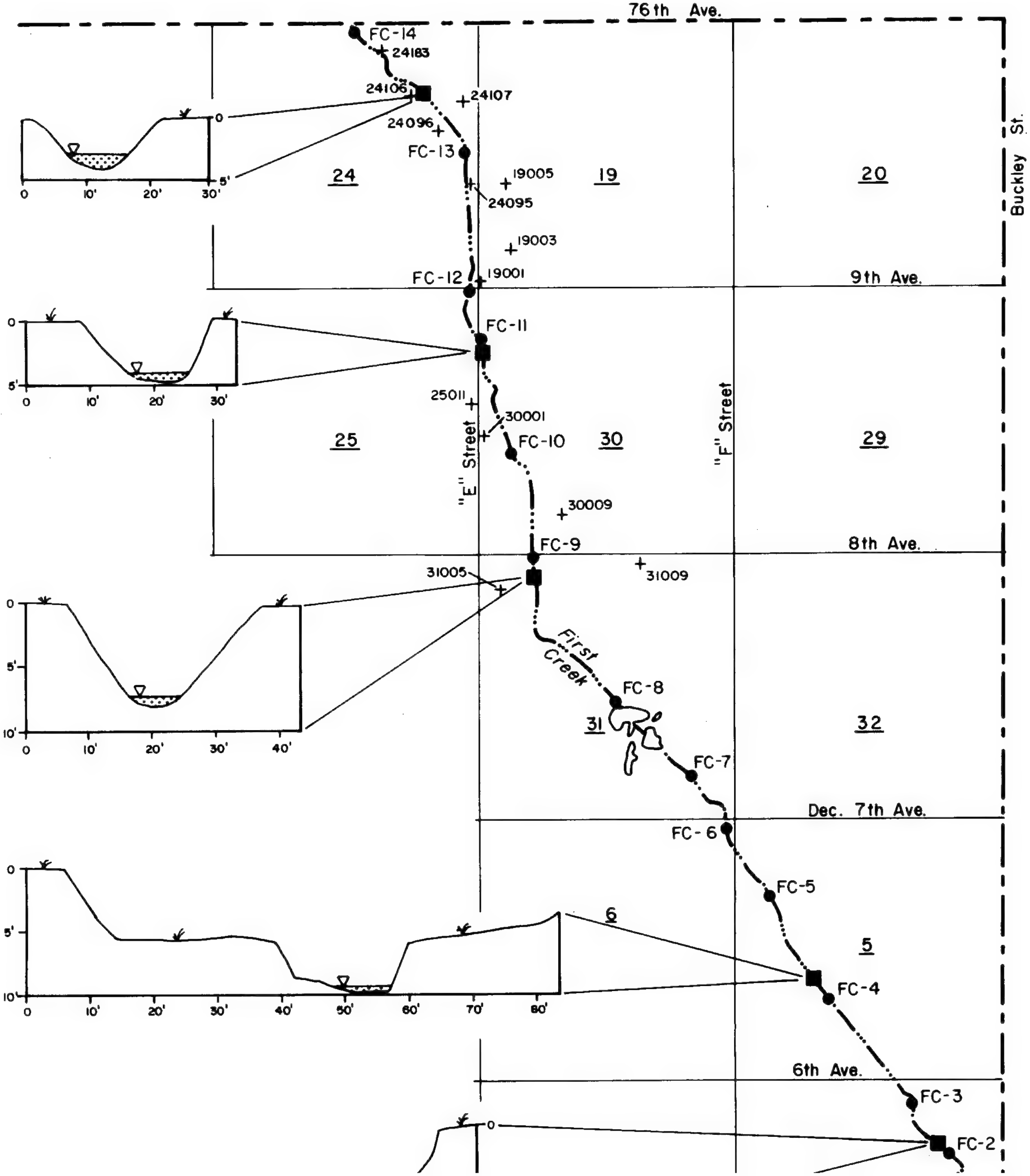
Figure 2.3-1

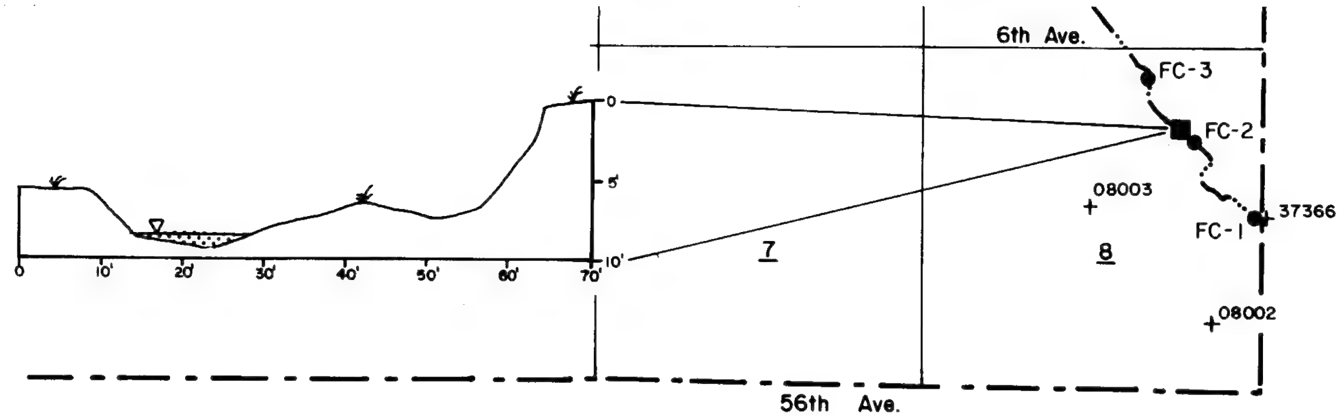
Detail of First Creek Drainage

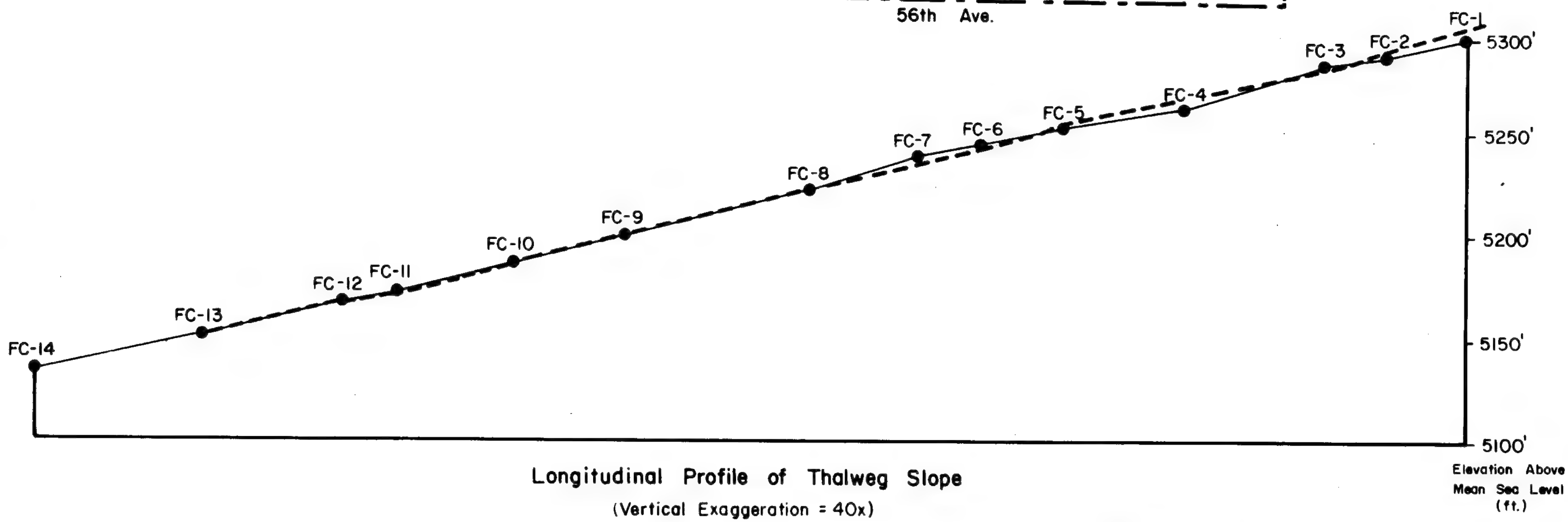
CMP SW FY89

Cross Sections

(Vertical Exaggeration = 2x)







Longitudinal Profile of Thalweg Slope
(Vertical Exaggeration = 40x)

Legend

7 Section Number

RMA Boundary

Stream or Ditch

Area of Ponded Water

FC-8 Survey Elevation Location

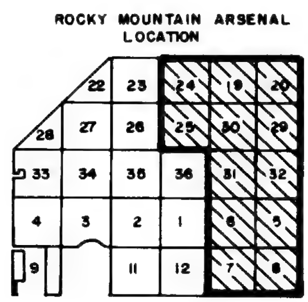
Cross Section Location

Water Table Elevation (April, 1989)

08002 Monitoring Well Location

Cross-Sectional Morphology of First Creek Stream Flow

Water Surface



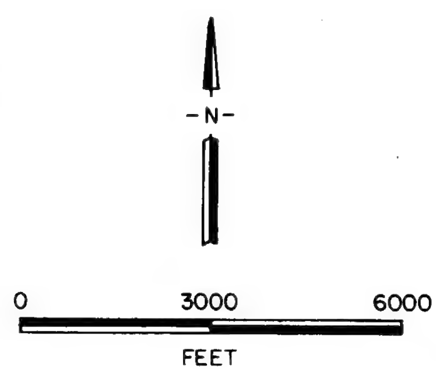


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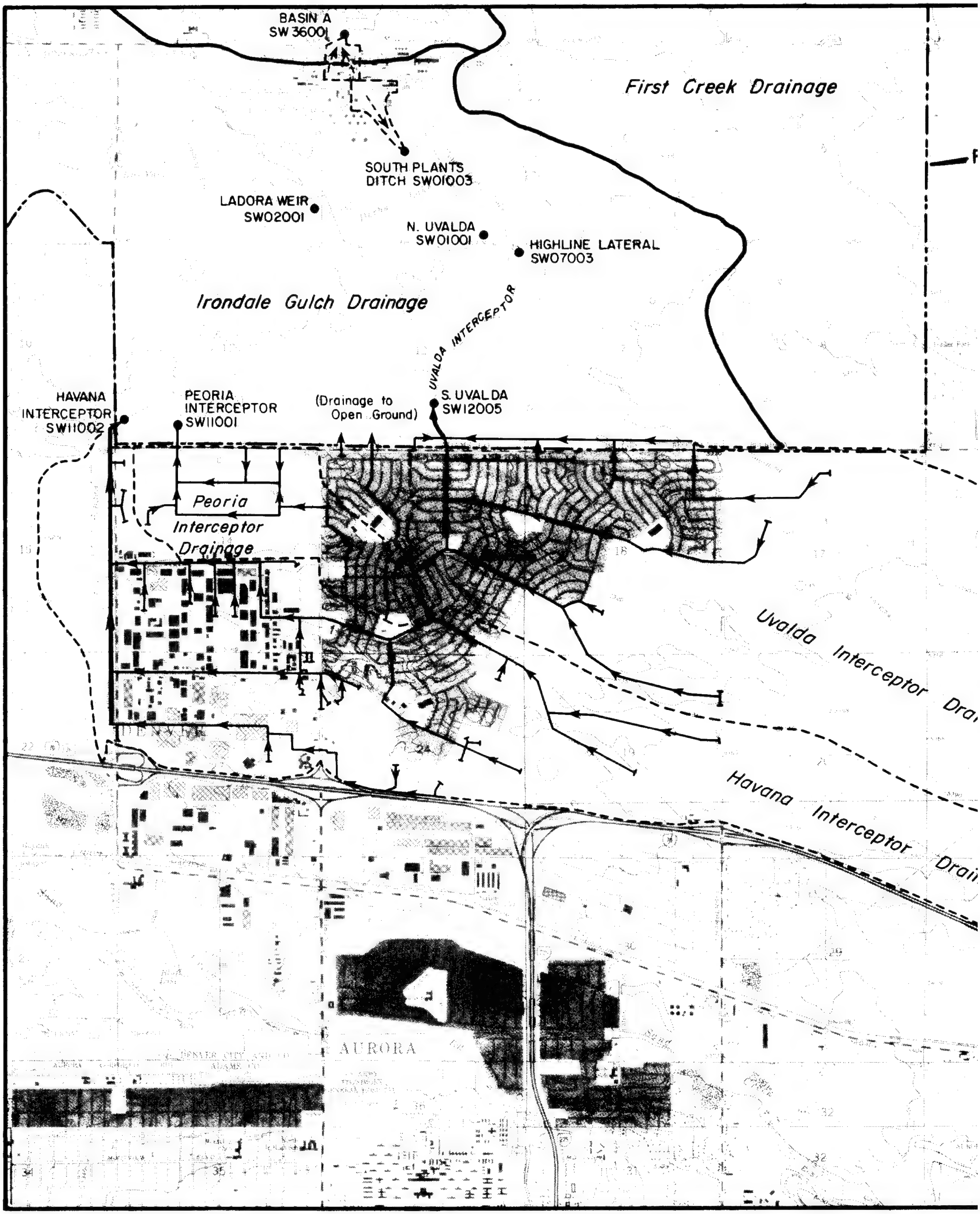
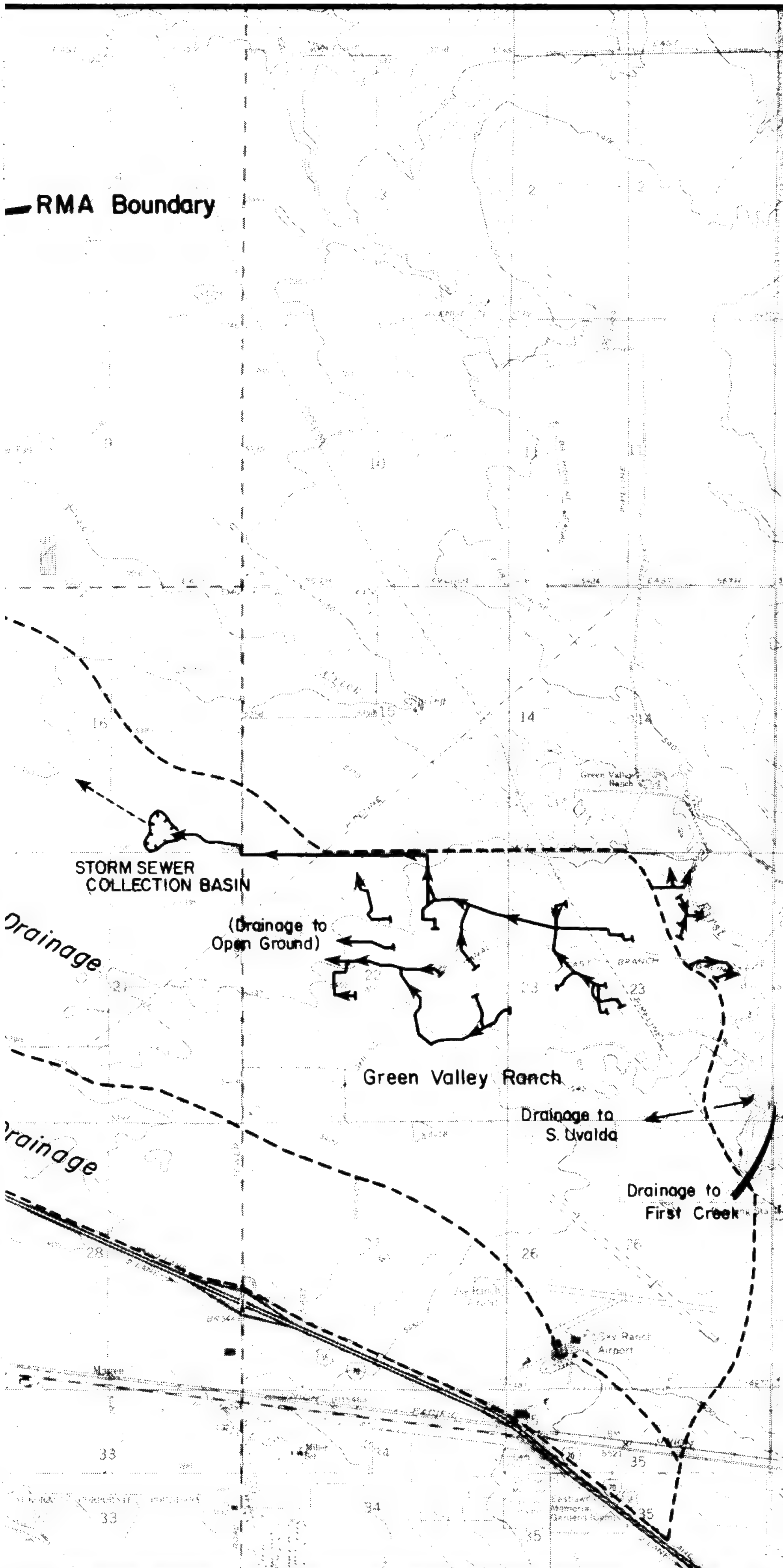
Figure 2.3-2

Thalweg Slope and
Cross Sections of First Creek

CMP SW FY89



BASIN A
SW36001
First Creek Drainage
SOUTH PLANTS
DITCH SW01003
LADORA WEIR
SW02001
N. UVALDA
SW01001
HIGHLINE LATERAL
SW07003
Irondale Gulch Drainage
UVALDA INTERCEPTOR
HAVANA
INTERCEPTOR
SW11002
PEORIA
INTERCEPTOR
SW11001
(Drainage to
Open Ground)
S. UVALDA
SW12005
Peoria
Interceptor
Drainage
Uvalda Interceptor Dra
Havana Interceptor Drai
AURORA



Legend

Storm Sewer Main or Ditch with Flow Direction

Water Level Monitoring Station

Drainage Basin Boundary

Storm Runoff Direction

-N-

0 3000 6000
FEET

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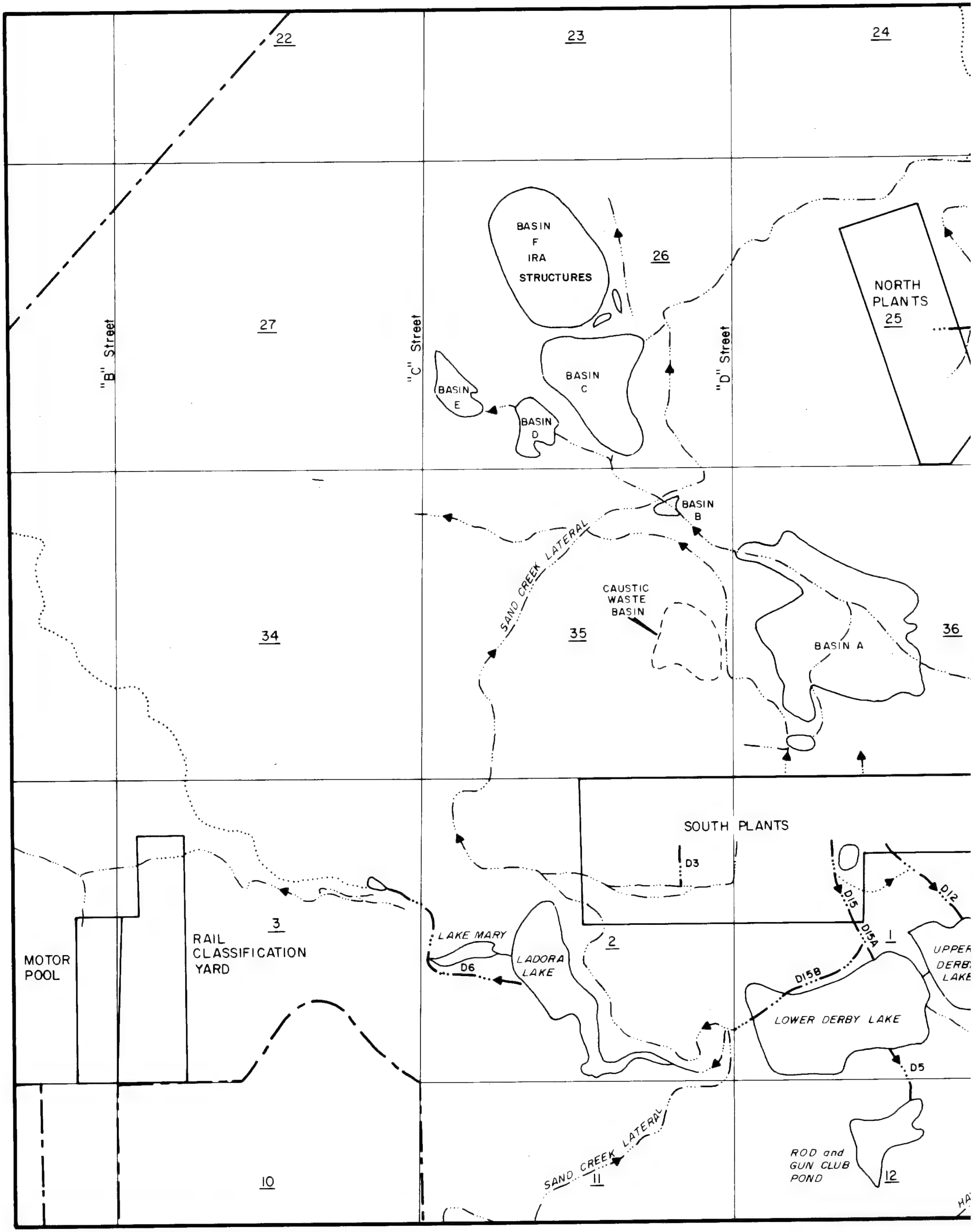
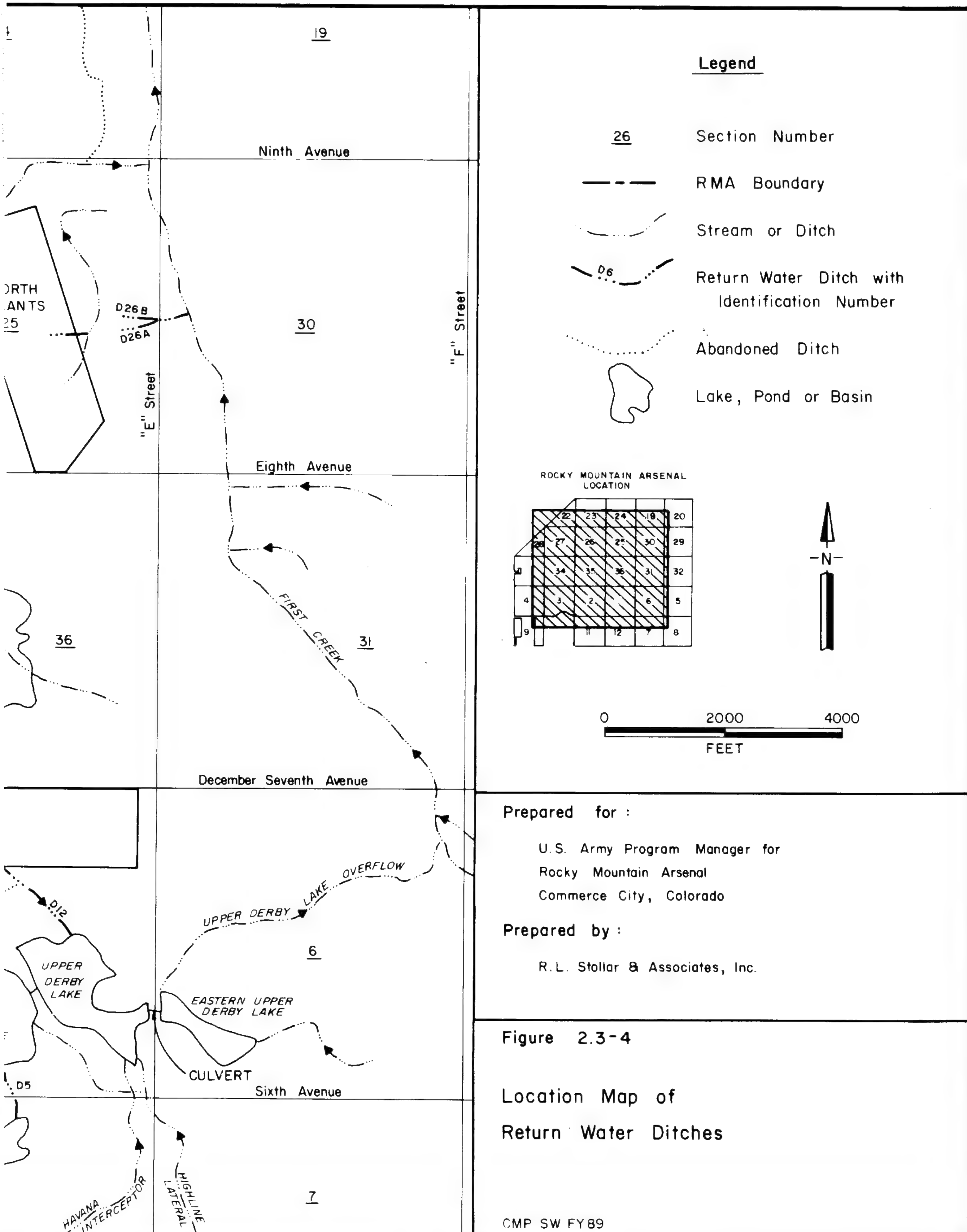
Figure 2.3-3

Detail of South Boundary Storm Sewer Drainages

CMP SW FY89


22
23
24
BASIN
F
IRA
STRUCTURES
26
NORTH
PLANTS
25
"B" Street
27
"C" Street
BASIN
C
"D" Street
BASIN
E
BASIN
D
BASIN
B
SAND CREEK LATERAL
CAUSTIC
WASTE
BASIN
34
35
BASIN A
36
SOUTH PLANTS
D3
D15
D12
D15A
1
UPPER
DERBY
LAKE
LAKE MARY
LADORA
LAKE
D6
2
3
RAIL
CLASSIFICATION
YARD
MOTOR
POOL
D15B
LOWER DERBY LAKE
D5
SAND CREEK LATERAL
10
11
ROD and
GUN CLUB
POND
12



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Commerce City, Colorado

Prepared by :

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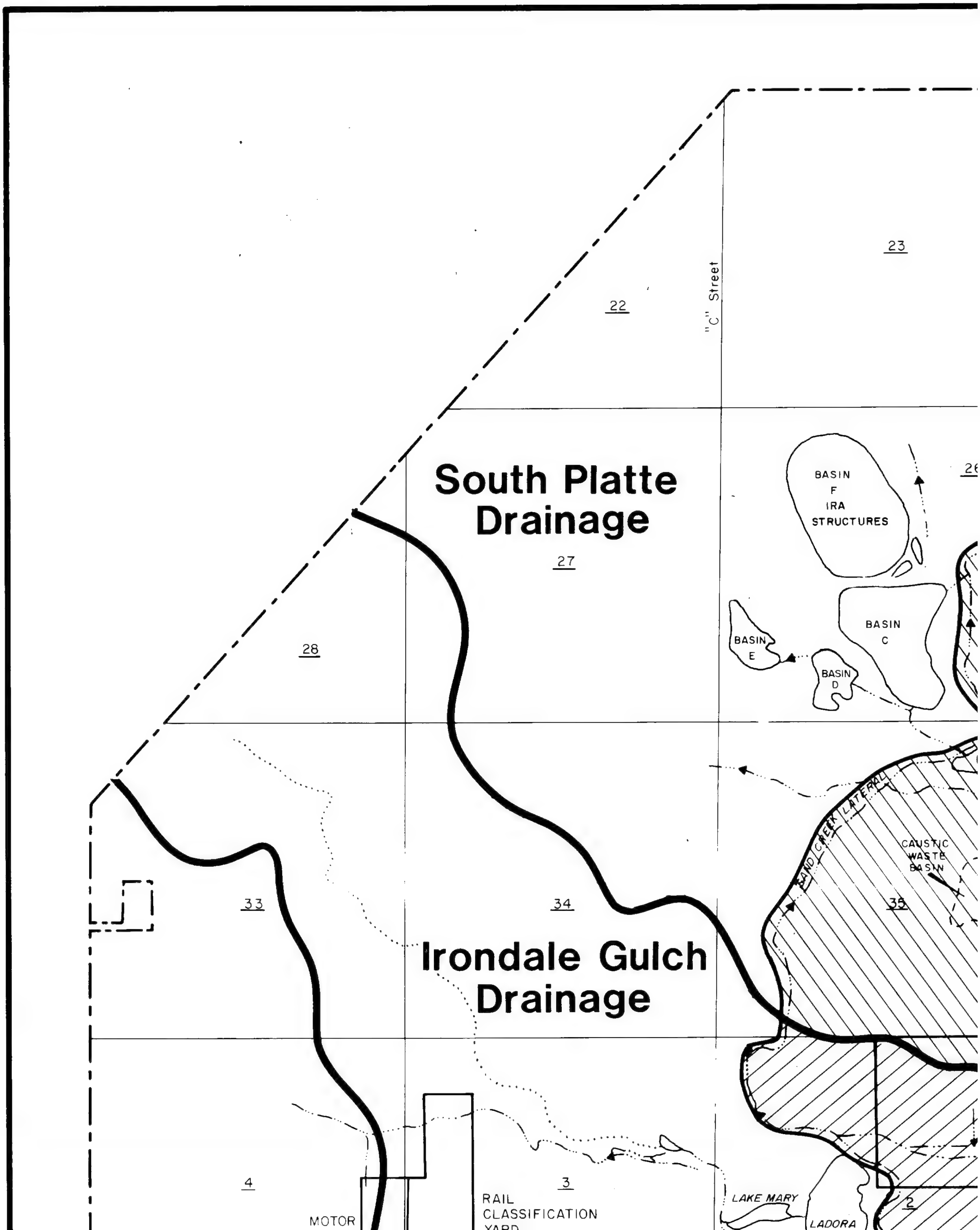
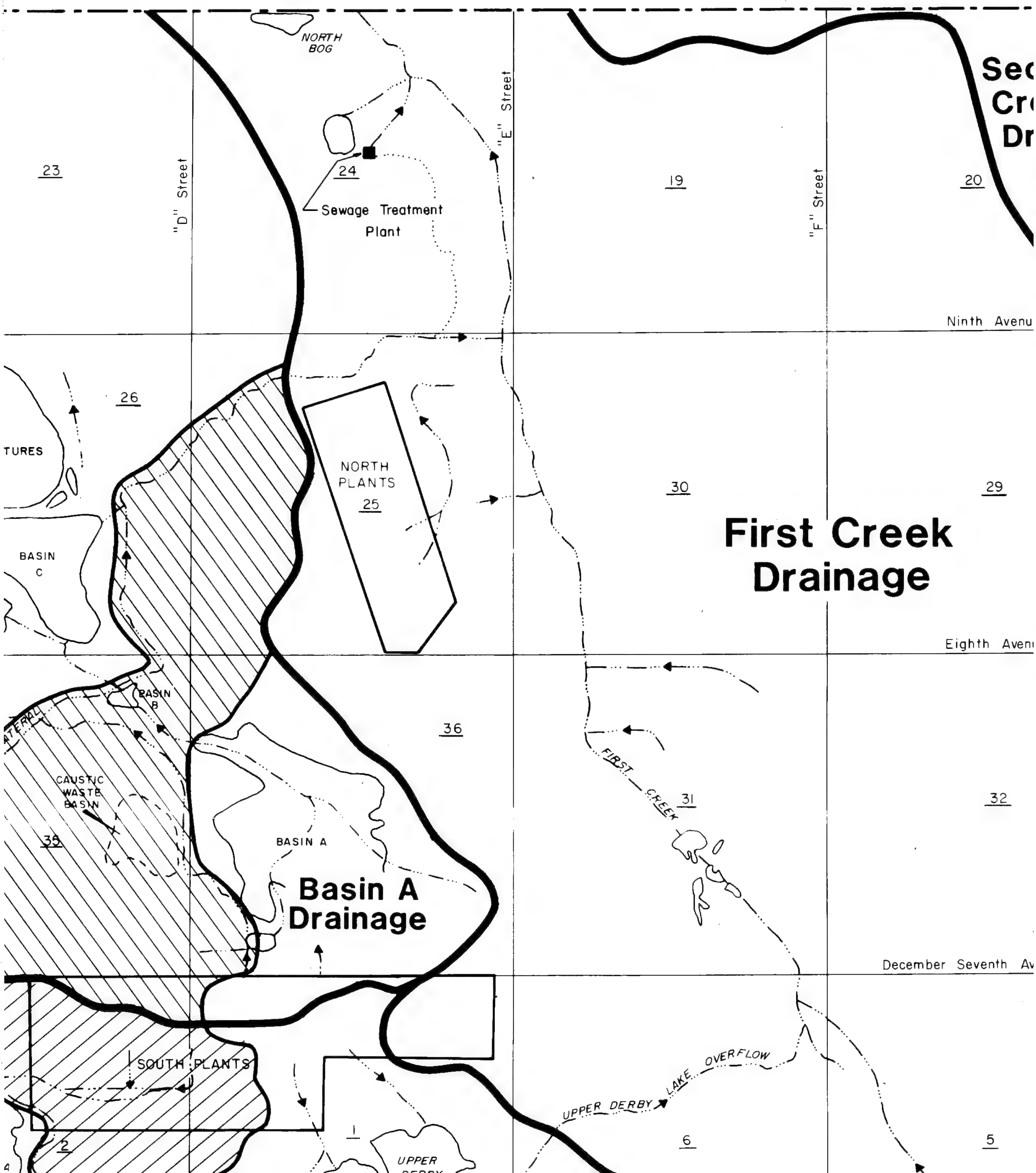
Figure 2.3-4

Location Map of Return Water Ditches

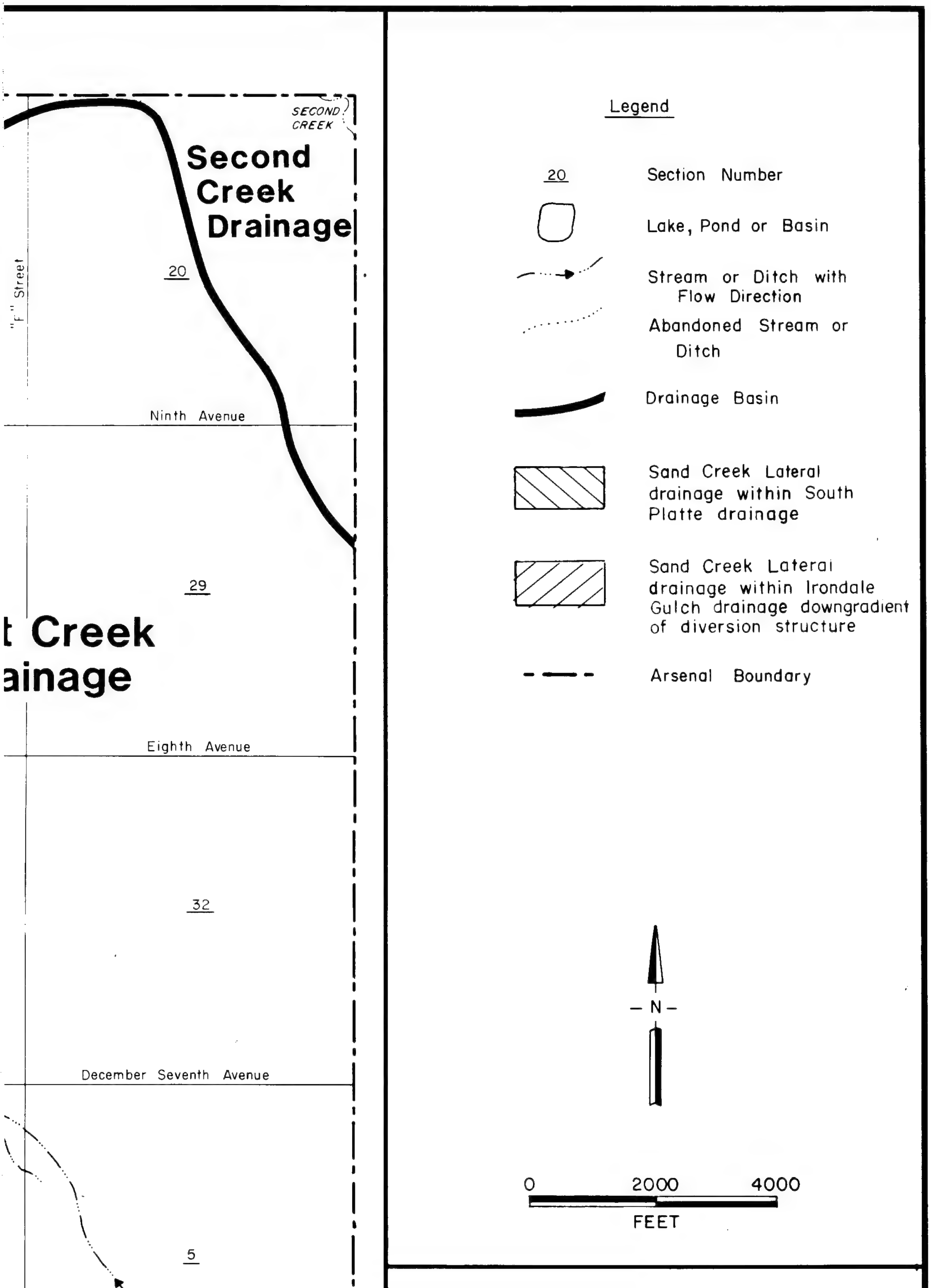
CMP SW FY89



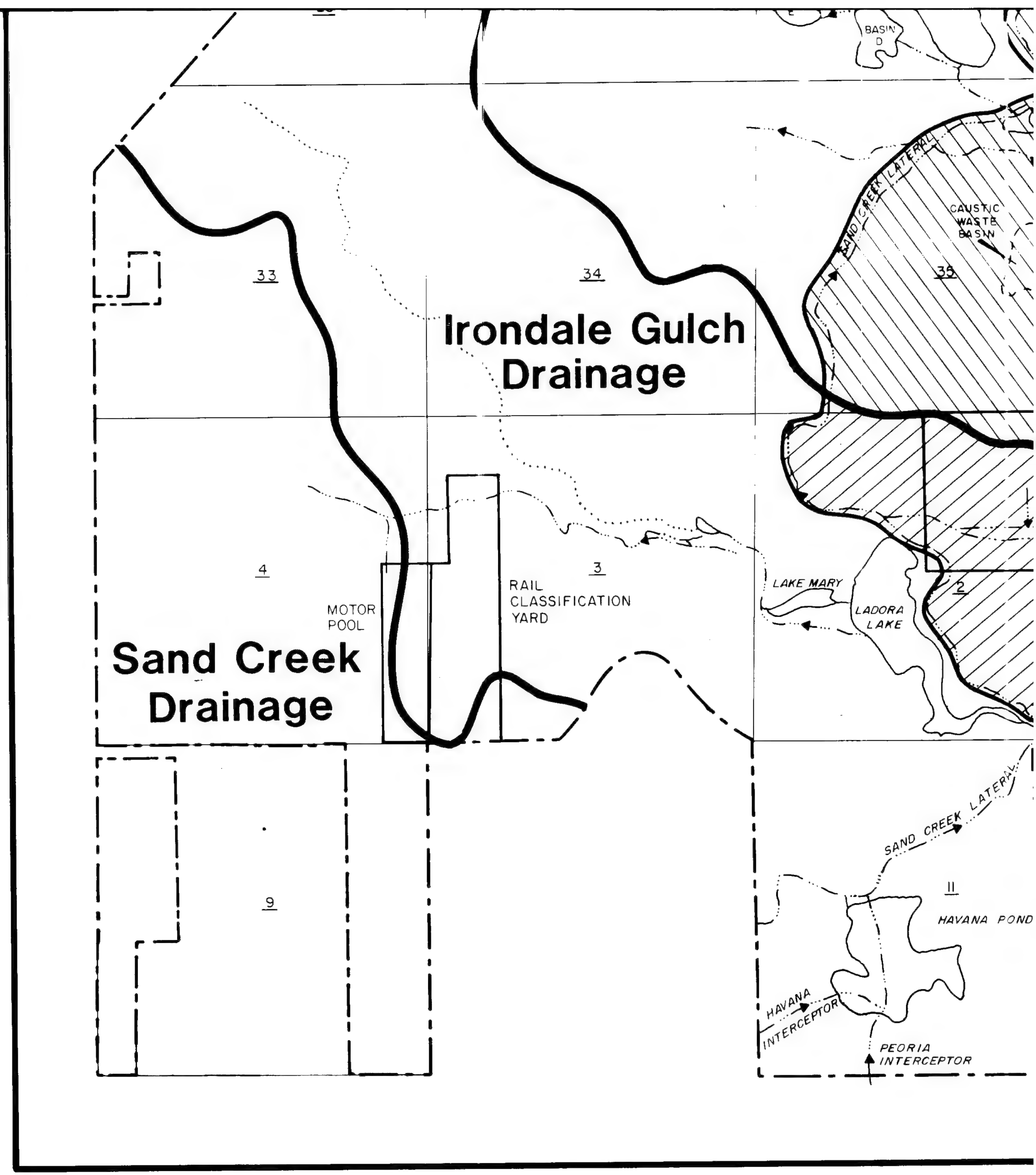
South Platte Drainage
Irondale Gulch Drainage
22
23
26
27
28
33
34
35
4
3
2
"C" Street
BASIN F IRA STRUCTURES
BASIN C
BASIN E
BASIN D
CAUSTIC WASTE BASIN
SAND CREEK LATERAL
RAIL CLASSIFICATION YARD
MOTOR
LAKE MARY
LADORA

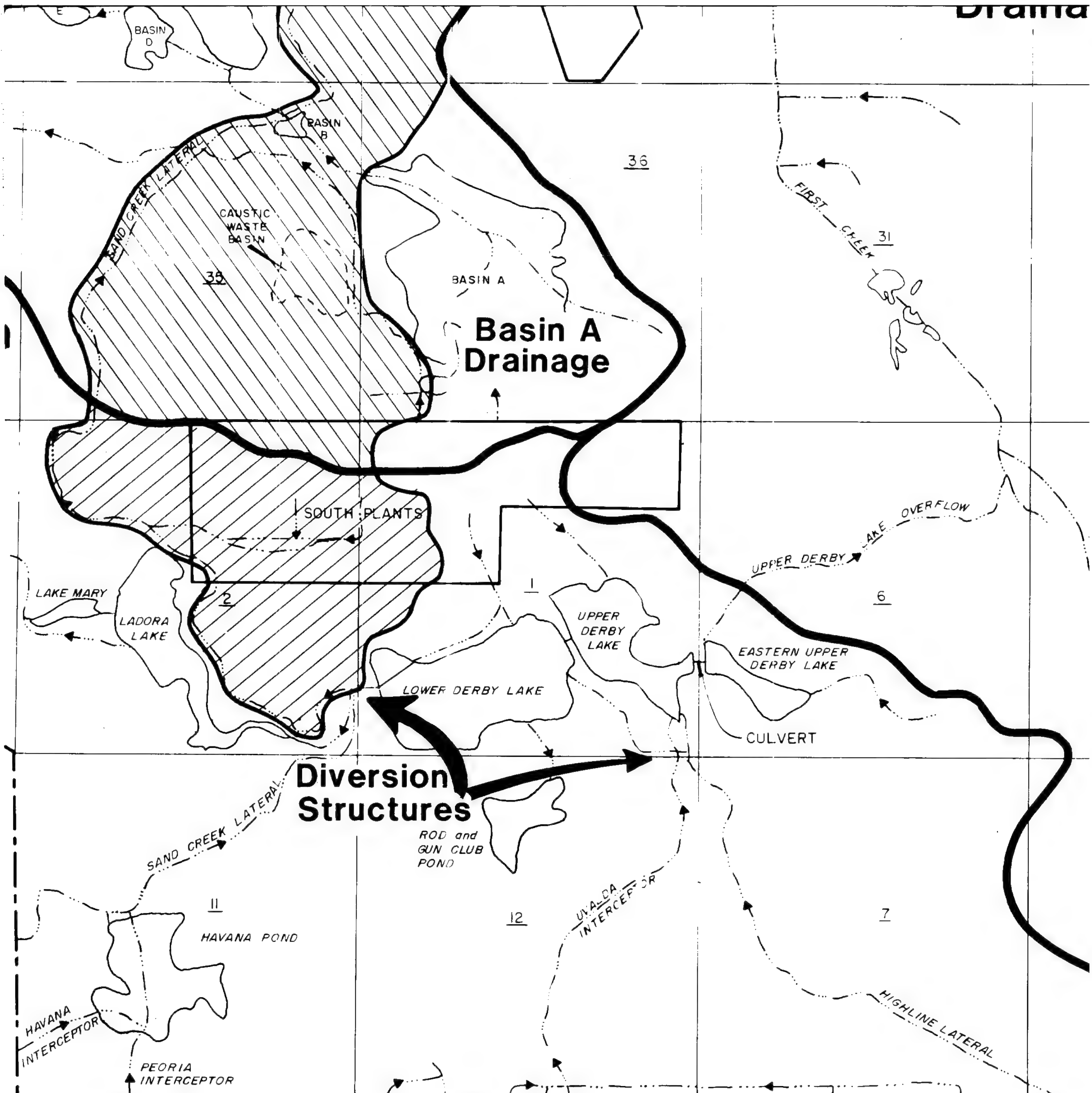


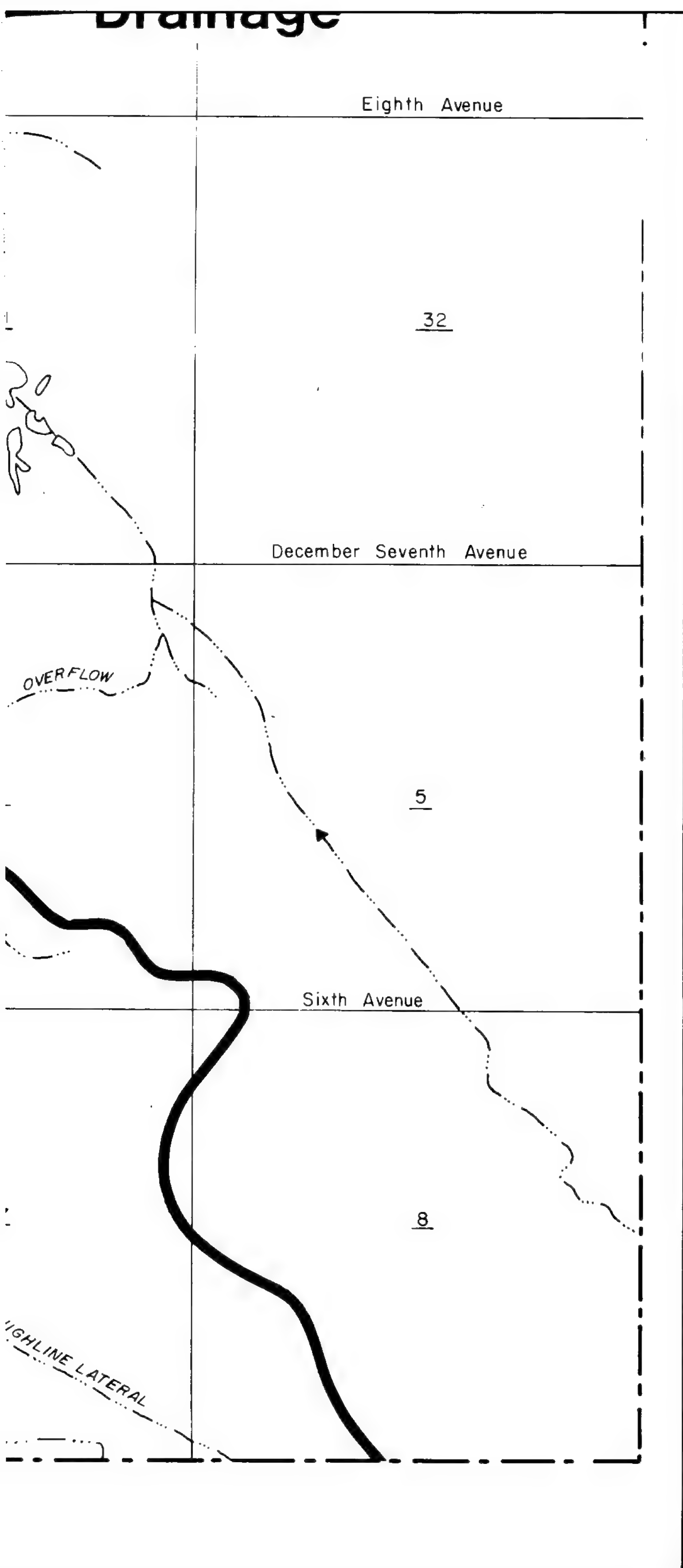
NORTH BOG
"E" Street
"D" Street
"F" Street
23
24
19
20
Sewage Treatment Plant
Sec
Cr
Dr
Ninth Avenu
26
TURES
NORTH PLANTS
25
30
29
BASIN C
First Creek Drainage
Eighth Aven
BASIN B
36
CAUSTIC WASTE BASIN
FIRST CREEK
31
32
35
BASIN A
Basin A Drainage
December Seventh Av
SOUTH PLANTS
UPPER DERBY LAKE OVERFLOW
2
1
UPPER
6
5

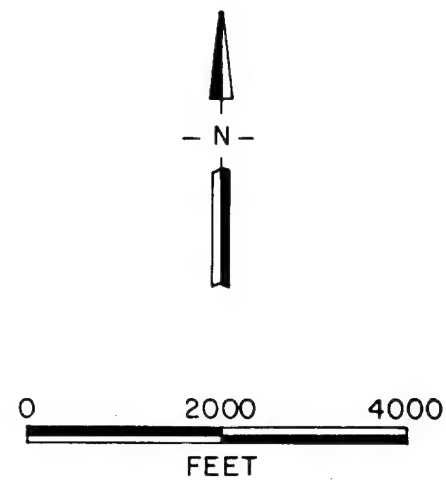


SECOND CREEK
Second Creek Drainage
20
"F" Street
Ninth Avenue
29
t Creek
ainage
Eighth Avenue
32
December Seventh Avenue
5
Legend
20
Section Number
Lake, Pond or Basin
Stream or Ditch with Flow Direction
Abandoned Stream or Ditch
Drainage Basin
Sand Creek Lateral drainage within South Platte drainage
Sand Creek Lateral drainage within Irondale Gulch drainage downgradient of diversion structure
Arsenal Boundary
N
0
2000
4000
FEET


BASIN D
CAUSTIC WASTE BASIN
SAND CREEK LATERAL
33
34
35
Irondale Gulch Drainage
4
3
2
MOTOR POOL
RAIL CLASSIFICATION YARD
LAKE MARY
LADORA LAKE
Sand Creek Drainage
9
SAND CREEK LATERAL
11
HAVANA POND
HAVANA INTERCEPTOR
PEORIA INTERCEPTOR


Draina
BASIN D
BASIN B
SAND CREEK LATERAL
CAUSTIC WASTE BASIN
35
36
FIRST CREEK
31
BASIN A
Basin A Drainage
SOUTH PLANTS
1
2
LAKE MARY
LADORA LAKE
UPPER DERBY LAKE
EASTERN UPPER DERBY LAKE
UPPER DERBY LAKE OVERFLOW
6
LOWER DERBY LAKE
CULVERT
Diversion Structures
ROD and GUN CLUB POND
SAND CREEK LATERAL
11
HAVANA POND
12
7
HIGHLINE LATERAL
HAVANA INTERCEPTOR
PEORIA INTERCEPTOR





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U.S. Army Program Manager for
Rocky Mountain Arsenal
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Prepared by :

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Plate 2.3-1

Diagram of RMA Surface-Water Features and Drainage Basins

CMP SW FY89

3.0 PROGRAM STRATEGY AND METHODOLOGY

3.1 Surface-Water Quantity

This section discusses the procedures, strategies, and equipment used to acquire surface-water quantity data. Stage and instantaneous discharge data were obtained from existing and new RMA surface-water monitoring stations (see Plate 1.3-1). These stations had been constructed for previous surface-water monitoring programs and reconstructed during the 1989 Surface-water program to monitor surface water flowing onto and off of RMA. This water quantity assessment effort undertaken by surface water CMP is summarized in monthly water quantity data (Appendix A) and is used in remediation efforts at RMA. The quantity of water that enters and exits RMA in the form of precipitation, surface runoff, evaporation and operational use is utilized to determine the effects on ground water at RMA and to develop plans for surface water management. Plate 1.3-1 shows the locations of each surface-water quantity monitoring station and their locations within the major RMA drainage basins described in Section 2. A single notation system was developed during FY88 to identify both stream discharge monitoring stations and water-quality sampling stations. Each monitoring station was assigned a corresponding water-quality number, as shown on Plate 1.3-1.

3.1.1 Surface-Water Monitoring Network

This section describes the surface-water quantity monitoring stations and is subdivided into major drainage basins that are monitored on RMA. First Creek Drainage Basin, Irondale Gulch Drainage Basin and South Platte Drainage Basin have surface-water quantity monitoring stations. Second Creek Drainage Basin and Sand Creek Drainage Basin do not have surface-water quantity monitoring stations because significant flows do not occur on RMA within these areas.

Each stream, lake, pond and diversion monitoring station was equipped, constructed and strategically located by previous contractors and by Stollar surface-water CMP to accurately monitor surface-water volumes for use in water management and remediation efforts. This section describes the equipment and controls used and the surface water that is characteristically monitored at each station within the major drainage basins described in Section 2 (Table 3.1-1).

Surface-water quantity monitoring under the CMP was conducted during Water Year 1989 at 17 monitoring stations located in three major drainage basins on RMA (Plate 1.3-1). Surface-water quantity monitoring activities included weekly monitoring of continuous gage recording stations, and monthly instantaneous discharge measurements at sites with active streamflow. In addition,

Table 3.1-1 Surface-Water Monitoring Network

Site	Monitoring Equipment
Irondale Gulch Drainage Basin	
Havana Interceptor (SW11002)	Concrete Lined Channel Control and CR-10 Data Logger/Bubbler System
Peoria Interceptor (SW11001)	90° V-notch Weir Compound Control, Stevens Type F Recorder, Style C Staff Gage, and DP115 Datapod
Ladora Weir (SW02001)	Rectangular Weir Section Control, Stevens Type F Recorder, Style C Staff Gage, and DP115 Datapod
South Uvalda Interceptor (SW12005)	Concrete V-notch Weir Compound Control, Stevens Type F Recorder, Style C Staff Gage, and CR-10 Data Logger/Bubbler System
North Uvalda Interceptor (SW01001)	Concrete Weir Compound Control, Stevens Type F Recorder, Style C Staff Gage, and DP115 Datapod
Highline Lateral (SW12007)	Cipolletti Weir Section Control, Stevens Type F Recorder, and Style C Staff Gage
South Plants Ditch (SW01003)	Sharp-crested V-notch Compound Control Weirs, Stevens Type F Recorder, and Style C Staff Gage
Havana Pond (SW11003)	Stevens Type F Recorder, Style C Staff Gage, and DP115 Datapod
Upper Derby Lake (SW01004)	Staff Gage
Lower Derby Lake (SW01005)	Staff Gage
Ladora Lake (SW02003)	Staff Gage
Lake Mary (SW02004)	Style C Staff Gage
First Creek Drainage Basin	
South First Creek (SW08003)	Concrete V-notch Weir Compound Control, Stevens Type F Recorder, Style C Staff Gage, and CR-10 Data Logger/Bubbler System

Table 3.1-1 Surface-Water Monitoring Network (continued)

Site	Monitoring Equipment
North First Creek (SW24002)	Concrete V-notch Weir Compound Control, Stevens Type F Recorder, Style C Staff Gage, and CR-10 Data Logger/Bubbler System
First Creek Off-Post (SW37001)	Concrete Triangular-throated Flume Control, Stevens Type F Recorder, DP115 Datapod and Style C Staff Gage
Sewage Treatment Plant (SW24001)	Totalizing Flow Meter
<u>South Platte Drainage Basin</u>	
Basin A Inflow (SW36001)	90° V-notch Weir Section Control, Stevens Type F Recorder, Style C Staff Gage, and DP115 Datapod

weekly staff gage readings were recorded at all stream and lake monitoring stations and the flow at the Sewage Treatment Plant in Section 24 was observed weekly. Table 3.1-2 provides a summary of Water Year 1989 monitoring activities that occurred in the three major drainage basins on RMA.

3.1.1.1 Irondale Gulch Drainage Basin. The Irondale Gulch Drainage Basin is located in the southwestern half of RMA, and is bordered by the South Platte Drainage Basin and the First Creek Drainage Basin to the northeast and by the Sand Creek Drainage Basin to the southwest (Plate 2.3-1). Included within the Irondale Gulch Drainage Basin is a portion of the Sand Creek Lateral Subdrainage Basin (Plate 2.3-1). Irondale Gulch Drainage Basin accepts surface-water flow from Havana Interceptor, Peoria Interceptor, Uvalda Interceptor, and Highline Lateral. The surface-water from these sources enter the drainage from the southern border of RMA and are directed to either Havana Pond or the South Plants Lakes. Flow can also be diverted to the Sand Creek Lateral Subdrainage Basin via Ladora Weir and/or Havana Pond. There is not a defined stream channel that exits RMA within the Irondale Gulch Drainage Basin, however, the drainage basin exits RMA in its northern half along the northwestern border.

There are a total of twelve monitoring stations located within the Irondale Gulch Drainage Basin (Plate 1.3-1). Stream monitoring stations include Havana Interceptor (SW11002), Peoria Interceptor (SW11001), Ladora Weir (SW02001), South Uvalda (SW12005), North Uvalda (SW01001), Highline Lateral (SW12007) and South Plants Ditch (SW01003). Lake and Pond monitoring stations include Havana Pond (SW11003), Upper Derby Lake (SW01004), Lower Derby Lake (SW01005), Ladora Lake (SW02003) and Lake Mary (SW02004). Monitoring equipment that is in service at the surface-water gaging stations within Irondale Gulch Drainage Basin is listed in Table 3.1-1.

3.1.1.1.1 Havana Interceptor (SW11002). - The Havana Interceptor gaging station is located near the southern boundary of RMA in the southwest corner of Section 11 (Plate 1.3-1). The purpose of the station is to monitor surface water flowing from the south onto RMA and the into the Irondale Gulch Drainage Basin. The Interceptor is a concrete lined channel and is designed to carry surface runoff and storm waters flowing to Havana Pond from Stapleton Airport and from commercial properties located south of RMA (Plate 1.3-1). The station was equipped with a Campbell Scientific CR-10 data logger and bubbler system in April 1989. The CR-10 data logger and a nitrogen cylinder for the bubbler system is housed inside a wooden storage shed at the station. Staff gage measurements are taken by placing a metal tape measure next to the copper bubbler line in the channel bottom. Prior to the installation of the data logger, the station was equipped with a Stevens Type F Recorder mounted on top of a corrugated metal pipe stilling well. The entire structure was suspended over the center of the concrete channel from a bridge constructed of two parallel telephone pole segments. Attached to the stilling well was a Style C porcelain enameled iron

Table 3.1-2 Surface-water Monitoring Station Activities

Station	Type	Activity		
		Weekly	Monthly	Storm Event
Irondale Gluch Drainage Basin				
Havana Interceptor (SW11002)	Recording Station	Service Recorders & Monitor Staff Gage	Discharge Measurement	Discharge Measurement/ Monitor Crest Stage
Peoria Interceptor (SW11001)	Recording Station	Service Recorders & Monitor Staff Gage	Discharge Measurement	Monitor Crest Stage
Ladora Weir (SW02001)	Recording Station	Service Recorders & Monitor Staff Gage	Discharge Measurement/ When Flow Occurs	
South Uvalda (SW12005)	Recording Station	Service Recorders & Monitor Staff Gage	Discharge Measurement/	Discharge Measurement/ Monitor Crest Stage
North Uvalda (SW01001)	Recording Station	Service Recorders & Monitor Staff Gage	Discharge Measurement	
Highline Lateral (SW12007)	Recording Station	Service Recorders & Monitor Staff Gage	Discharge Measurement/ When Flow Occurs	
South Plants Ditch (SW01003)	Recording Station	Service Recorder & Monitor Staff Gage		Discharge Measurement/ Monitor Crest Stage
Havana Pond (SW11003)	Recording Station	Service Recorders & Monitor Staff Gage		
Upper Derby Lake (SW01004)	Staff Gage	Monitor Staff Gage	Monitor Gage	Monitor Gage

Table 3.1-2 Surface-Water Monitoring Station Activities (continued)

		Activity		
Station	Type	Weekly	Monthly	Storm Event
Irondale Gulch Drainage Basin (continued)				
Lower Derby Lake (SW01005)	Staff Gage	Monitor Staff Gage	Monitor Gage	Monitor Gage
Ladora Lake (SW02003)	Staff Gage	Monitor Staff Gage	Monitor Gage	Monitor Gage
Lake Mary (SW02004)	Staff Gage	Monitor Staff Gage	Monitor Gage	Monitor Gage
First Creek Drainage Basin				
South First Creek (SW08003)	Recording Station	Service Recorders & Monitor Staff Gage	Discharge Measurement	Discharge Measurement/ Monitor Crest Stage
North First Creek (SW24002)	Recording Station	Service Recorders & Monitor Staff Gage	Discharge Measurement	Discharge Measurement/ Monitor Crest Stage
First Creek Off-Post (SW37001)	Recording Station	Service Recorders & Monitor Staff Gage	Discharge Measurement	Discharge Measurement/ Monitor Crest Stage
Sewage Treatment Plant (SW24001)	Flow Meter	Monitor Meter		
South Platte Drainage				
Basin A (SW36001)	Recording Station	Service Recorders & Monitor Staff Gage	Discharge Measurement	Discharge Measurement/ Monitor Crest Stage

SWR-89-M.TBL

staff gage. The stilling well, Stevens recorder and staff gage were removed in March 1989. The channel control structure at the station is a concrete trapezoidal channel. There are not any additional control structures near the gaging station.

Before the removal of the Stevens Type F recorder and stilling well, the station required an abnormal amount of maintenance due to accumulations of debris around the stilling well. The water quantity record was also adversely affected because the stilling well obstructed the channel's normal flow of water. In its present configuration, however, the station requires minimal maintenance and will be able to provide water quantity records throughout the winter months. The nitrogen tank for the CR-10 bubbler system is replaced when tank pressure drops to less than 200 psi, and the CR-10's battery is replaced when it drops below 12 volts. The RAM pack storage module on the data logger can be changed monthly or data can be downloaded directly to a PC compatible computer.

3.1.1.1.2 Peoria Interceptor (SW11001). - The Peoria Interceptor gaging station is located near the southern boundary of RMA, in the southwest quarter of Section 11 (Plate 1.3-1). The purpose of the station is to monitor surface water flowing from the south onto RMA Irondale Gulch Drainage Basin. It is situated in an unlined ditch designed to carry surface and storm sewer runoff from the off-post industrial area to Havana Pond, as described previously in Section 2.3. The station is equipped with a Stevens Type F recorder in conjunction with a potentiometer and an Omnidata International DP115 datapod on top of a corrugated metal pipe stilling well which is connected hydraulically to the active stream channel by 2-inch intake pipes. A Style C staff gage is attached to the stilling well. The compound control structure located at the station is a 90° V-notch steel plate weir attached to a narrow plank that is positioned perpendicular to flow and embedded into the banks on both sides of the channel.

The problems that are encountered at this station consist of an accumulation of debris, vegetation overgrowth, and a backwatering situation. The station collects trash that is removed periodically, and vegetation overgrowth at the station needs to be removed annually. A backwater condition exists at this station when the water stored in Havana Pond exceeds 4.0 ft on the Havana Pond staff gage, which occurs during extreme storm events resulting in the loss of some flow data during this period. The weir was refabricated during April 1989 in order to correct leaking through, underneath, and around the old weir. Additional maintenance consists of changing the data storage module (DSM) and batteries in the datapod every month.

3.1.1.1.3 Havana Pond (SW11003). - The Havana Pond gaging station is located adjacent to the earthen embankment on the north side of Havana Pond near the center of Section 11 (Plate 1.3-1) in the Irondale Gulch Drainage Basin. The pond is used to store surface and storm runoff from the Havana and Peoria Interceptors. The station consists of a Stevens Type F recorder in conjunction with a potentiometer and a DP115 datapod housed in a protective cover that is mounted on a vertical stilling well. A Style C staff gage is mounted to a vertical post on the walkway leading to the stilling well. The stilling well is positioned near Havana Pond's low stage waterline and is hydraulically connected to the pond. This station was used historically to monitor storage at the pond. The existing outflow structure is made of an 18-inch diameter culvert with a gate that is kept shut except during extremely high pond stages. A spillway was constructed in October 1988 and was designed to accept pond water when the water exceeds 7.9 ft on the staff gage. The downstream end of the culvert and spillway empties into a poorly defined channel before entering Sand Creek Lateral about 25 ft away.

Maintenance that is required at the station consists of monthly changing of the data storage module and batteries in the datapod. Water levels in the pond go below the stilling well and staff gage during drier times of the year. To eliminate the problem, a trench is excavated to hydraulically connect the pond with the stilling well and staff gage. The stilling well also accumulates sediment which must be periodically removed to keep the Stevens Type F recorder's float in water.

3.1.1.1.4 Ladora Weir (SW02001). - The Ladora Weir gaging station is located in the southeast corner of Section 2 (Plate 1.3-1) in the Irondale Gulch Drainage Basin. The station monitors flows in the channel complex coming out of Lower Derby Lake and going into Ladora Lake or Sand Creek Lateral. However, Ladora Weir does not monitor flows originating from Havana Pond that go into Sand Creek Lateral. The gaging station consists of a Stevens Type F recorder in conjunction with a potentiometer and a DP115 datapod in a protective cover that is fitted onto a wooden deck. Beneath the deck is a concrete basin that receives flow from Lower Derby Lake. A stilling well and a Style C staff gage are also located in this concrete basin. The section control at the station is a standard suppressed rectangular weir constructed of two 2-inch wide planks fitted on top of the concrete basin wall.

The station's datapod requires monthly changing of the DSM and batteries. This station does not accumulate trash and vegetative debris but the weir displays leaks through and around the wooden planks.

3.1.1.1.5 South Uvalda (SW12005). - The South Uvalda gaging station is located on the southern portion of Uvalda Interceptor in south central Section 12 (Plate 1.3-1). It is situated in an

unlined ditch and monitors surface and storm sewer waters originating from off-post residential and industrial properties flowing onto RMA and the Irondale Gulch Drainage Basin. Stream flow is directed to either of the Derby Lakes. The station is equipped with a CR-10 data logger and bubbler system, and a Stevens Type F recorder. The CR-10 data logger was installed during April 1989 and is housed inside a wooden storage shed along with a nitrogen tank for the bubbler system. The Stevens Type F recorder is enclosed in a steel protective cover on top of a steel-cased stilling well that is hydraulically connected to the active stream channel with 2-inch intake pipes. The compound control structure located at the station consists of a V-notch in a 12 in wide concrete weir. A Style C staff gage is located in the active channel near the intake pipes.

This station requires periodic maintenance. The nitrogen tank for the CR-10 bubbler system is replaced with a fully charged cylinder when the tank pressure drops to less the 200 psi on the regulator gage. The data logger's RAM pack storage module can be changed every month or data in the storage module can be downloaded to a PC compatible computer. The battery for the CR-10 is changed whenever the voltage drops to less than 12 volts. The station accumulates brush and trash, and the stream banks are nearly overgrown with vegetation. The brush and trash can be removed as needed, but the overgrowth is removed annually by Army personnel. The station's stilling well also requires periodic flushing because the intake pipes fill with silt.

3.1.1.1.6 North Uvalda (SW01001). - The North Uvalda gaging station is actually located on the original Highline Lateral ditch in the southeast corner of Section 1 in the Irondale Gulch Drainage Basin, approximately 1,500 ft upstream of the inlet to Lower Derby Lake (Plate 1.3-1). It is positioned on the segment of the ditch so that surface-water delivered to Lower Derby Lake can be monitored. This surface water originates from an area south of RMA, either from Highline Lateral or from Uvalda Interceptor canal. The station consists of a Stevens Type F recorder in conjunction with a potentiometer and DP115 datapod housed in a protective box that is mounted on a corrugated metal pipe stilling well. The stilling well is situated adjacent to the active stream channel and is hydraulically connected to the stream with 2-inch intake pipes. A Style C staff gage is positioned in the active channel at the stilling well's intake pipes. The compound control structure located at the station is a broad-crested concrete weir.

The station requires normal maintenance, such as brush and trash removal and flushing the stilling well intake pipes. The staff gage at this station was lowered to the ditch bottom in July 1989. Additionally, the data storage module and batteries are changed monthly in the datapod.

3.1.1.1.7 Highline Lateral (SW12007). - The Highline Lateral gaging station is located on the Highline Lateral, 20 ft south of 6th Avenue in the northeast corner of Section 12 (Plate 1.3-1)

in Irondale Gulch Drainage Basin. This station's number was changed this year from SW07003 to a number which reflects the section it is actually in. It is situated along the unlined Highline Lateral irrigation ditch, which delivers Army-owned shares of irrigation water from the South Platte River to the Derby Lakes. The station is equipped with a Stevens Type F recorder in a protective cover mounted on an open-ended wooden-cased feeder channel. The wooden feeder channel is hydraulically connected to the main channel and is located approximately 10 ft upstream from the control. This station was also equipped with a DP115 datapod for several months of Water Year 1989. The section control for the station is a Cipolletti weir.

The station does not collect excessive amounts of trash and vegetative debris. Eventually, a new stilling may be needed to replace the wooden feeder channel box. The stage record exhibits a broad trace rather than a clearly defined water level because the feeder box permits rippling water inside the well. A new stilling well would correct this problem. A Style C staff gage was installed opposite the feeder canal replacing the old standard staff gage.

3.1.1.1.8 South Plants Ditch (SW01003). - The South Plants Ditch gaging station is located near the center of Section 1 in the Irondale Gulch Drainage Basin (Plate 1.3-1) at a diversion structure that can monitor flow from the South Plants area, either to the east or to the west end of Lower Derby Lake. The station consists of a Stevens Type F recorder in a protective box that is mounted on a corrugated metal pipe stilling well which is hydraulically connected to the ditch with two 2-inch intake pipes. A Style C staff gage is positioned in the active ditch. The compound control structures located at the station are sharp-crested, 90° V-notch weirs. These are mounted on wooden planks attached to the outflow sides of the diversion structure. Flow can pass over both weirs at the same time, to either the upper or lower end of Lower Derby Lake.

This station did not require maintenance throughout Water Year 1989 because water flowed through South Plants Ditch during just two days throughout the entire year.

3.1.1.1.9 Lake Monitoring Stations. Staff gages that monitor lake levels are located at observation points on each of the lake dams. The lakes currently being monitored are Upper Derby Lake, Lower Derby Lake, Ladora Lake, and Lake Mary and are all within the Irondale Gulch Drainage Basin. Plate 1.3-1 shows the location of each lake observation point.

The Upper Derby Lake staff gage is located on the west shore of the lake near the outflow to Lower Derby Lake. The station number is SW01004. This staff gage is divided into increments of 0.1 ft and has a range of 0 to 10.0 ft. The lake will overflow its banks at a staff gage of approximately 9.0

ft. The elevation of the zero reference point was determined to be 5247.77 ft-mean sea level (ft-msl) on January 20, 1989.

The Lower Derby Lake staff gage is located on the west end of the lake near its outfall to Ladora Weir. The station number is SW01005. The staff gage is divided into increments of 0.1 ft and has a range of 3.0 to 21.0 ft. This lake will overflow at a gage reading of 21.2 ft. The zero reference elevation is 5230.17 ft-msl, as determined on February 22, 1989.

The Ladora Lake staff gage is located on the west end of the lake near the pump station. The number for this station is SW02003. A new staff gage was installed in September 1989. The staff gage has a precision of 0.1 ft and spans a vertical distance from 0 to 13.0 ft. Overflow will occur at 12.4 ft. The zero reference elevation of the staff gage is 5207.11 ft-msl, taken on October 11, 1989.

Water elevation at Lake Mary is monitored by a staff gage located on the west end of the lake. The designated number for this station is SW02004. A Style C staff gage with a precision of 0.01 ft and a range from 0 to 2.00 ft is used to monitor the lake levels. Overflow of the Lake Mary dam occurs at 1.34 ft. The zero reference elevation is 5202.39 ft-msl, as determined on January 20, 1989.

3.1.1.2 First Creek Drainage Basin. The First Creek Drainage Basin is located predominantly on the eastern half of RMA, and is bordered by the Second Creek Drainage Basin to the northeast and by the South Platte Drainage Basin at the Basin A Drainage Basin and the Irondale Gulch Drainage Basin to the west and southwest (Plate 2.3-1). The primary source of stream flow in First Creek Drainage Basin is from First Creek, but the drainage can also receive stream flow from Upper Derby Lake Overflow, Sand Creek Lateral, Highline Canal and the Sewage Treatment Plant (Plate 2.3-1). Surface water that exits RMA in the First Creek Drainage Basin is confined to First Creek where it flows off-post along the northern border.

There are four monitoring stations located within the First Creek Drainage Basin, and include South First Creek (SW08003), North First Creek (SW24002), First Creek Off-Post (SW37001), and the Sewage Treatment Plant (SW24001). Monitoring equipment that is employed at these stations is listed in Table 3.1-1.

3.1.1.2.1 South First Creek (SW08003). - With the construction of a retention pond immediately upstream of the South First Creek station, located in Section 5, and the subsequent rerouting of First Creek, the flow bypassed this station at the end of September 1988. A new station was constructed upstream of the retention pond on First Creek in Section 8. The new South First

Creek monitoring station is located in the northeast quarter of Section 8 (Plate 1.3-1) and is used to monitor flow coming onto RMA into the First Creek Drainage Basin. A new concrete V-notch weir was constructed in this area in a narrow reach of channel in October 1988. The station is equipped with a Stevens Type F recorder housed in a protective box and is mounted to a corrugated metal pipe stilling well that is hydraulically connected to the active stream with two 2-inch intake pipes. During April of 1989 the station was also equipped with a CR-10 data logger/bubbler system, which is housed inside a wooden storage shed with a nitrogen supply tank. The staff gage is a Style C gage and is located in the active stream channel. The compound control structure located at the station is a concrete V-notch weir.

Minimal maintenance is required at this station. The nitrogen tank for the CR-10 bubbler system is replaced when tank pressure drops below 200 psi, and the CR-10's battery is replaced when it drops below 12 volts. The RAM pack storage module on the data logger is also changed monthly or it can have its data downloaded directly to a PC compatible computer.

3.1.1.2.2 North First Creek (SW24002). - The North First Creek monitoring station is located in the northeast quarter of Section 24 in the First Creek Drainage Basin (Plate 1.3-1). This station monitors surface-water flows that leave RMA on First Creek. Installation of the station was completed in March 1989. The station is equipped with a Stevens Type F recorder housed in a protective box and is mounted to a corrugated metal pipe stilling well that is hydraulically connected to the stream channel with two 2-in intake pipes. A CR-10 data logger/bubbler system was installed during April 1989 and is housed in a wooden storage shed with a nitrogen supply tank. A Style C staff gage is positioned in the active stream channel opposite to the stilling well's intake pipes. The compound control structure at the station is a concrete V-notch weir and was constructed in October 1988.

Minimal maintenance is required at this station. The nitrogen supply tank for the CR-10 bubbler system is replaced when tank pressure drops below 200 psi, and the CR-10's battery is changed when it drops below 12 volts. The RAM pack storage module on the data logger is also changed monthly or it can have its data downloaded directly to a PC compatible computer. Periodic removal of some brush is also required following high winds.

3.1.1.2.3 First Creek Off-Post (SW37001). - The First Creek Off-Post monitoring station is located approximately one half mile north of RMA's northern boundary and directly southeast of Highway 2 (Plate 1.3-1) in the First Creek Drainage Basin. This station is used to monitor surface water flow that exists between the North First Creek station and this station. The First Creek Off-Post station did not record stage data following the winter of 1988 because water was flowing

beneath the H-flume and recording system. The station was determined to be nonrepairable and was redesigned and replaced in June 1989. The replacement included a new concrete triangular-throated flume. Stage data collection began in July 1989. The gaging house was originally equipped with a Stevens Type F recorder, DP115 datapod, and Style C staff gage, but vandalism during August 1989 rendered the station's record keeping inoperative the remainder of Water Year 1989. The station is now equipped with a Stevens Type F recorder and a Style C staff gage. The gaging house also serves as the stations stilling well which is hydraulically connected to the concrete flume by a 2 in intake pipe.

3.1.1.2.4 Sewage Treatment Plant (SW24001). - A totalizing flow meter records flow from the sewage treatment plant in Section 24 in the First Creek Drainage Basin (Plate 1.3-1). The Sewage Treatment Plant processes on-post sanitary sewer effluents and discharges treated water to a lined ditch that becomes unlined as it enters First Creek. The flow meter measures flow in hundreds of gallons and flow meter data was converted into gallons per day, gallon per week, and gallons per month. The meter is inside the building adjacent to the outfall. The meter is read by Army personnel on a daily basis and flow is monitored by CMP surface-water personnel weekly.

3.1.1.3 South Platte Drainage Basin. The South Platte Drainage Basin is located in the northwestern half of RMA, and is bordered by the First Creek Drainage Basin to the east and by the Irondale Gulch Drainage Basin to the southwest (Plate 2.3-1). The Basin A Subdrainage Basin and a portion of the Sand Creek Lateral Subdrainage Basin is located within the South Platte Drainage Basin (Plate 2.3-1). Stream flow in the South Platte Drainage Basin originates from the Basin A Inflow and terminates in the Basin A lime pond. There is not a defined stream channel that exits RMA within the South Platte Drainage Basin. The Sand Creek Lateral channel within the Sand Creek Lateral Subdrainage Basin crosses into the First Creek Drainage Basin near the northern border of the North Plants, however, flow in this channel is extremely rare (Plate 2.3-1).

The Basin A gaging station (SW36001) is the only surface-water monitoring station located in the South Platte Drainage Basin (Plate 1.3-1). Equipment that is in use at the station is listed in Table 3.1-1.

3.1.1.3.1 Basin A (SW36001). - The Basin A gaging station is located in a drainage ditch in the southwest corner of Section 36 (Plate 1.3-1), and is used to monitor storm sewer runoff and ground water which may be infiltrating from the South Plants area into the ditch and South Platte Drainage Basin. Surface waters flow past the structure into a concrete-lined channel that flows into the Basin A pond. The station consists of a Stevens Type F recorder in conjunction with a potentiometer and DP115 datapod in a protective box mounted on a corrugated metal pipe stilling well in the center of

the ditch. The section control structure located at the station is a steel 90° V-notch weir. A Style C staff gage is attached to the weir.

Maintenance that is required at the station consists of monthly changing of the data storage module and batteries in the datapod. Additionally, brush has to be removed periodically from the upstream and downstream sides of the weir.

3.1.2 Surface-Water Quantity Data Acquisition

The procedures and methods that were used to obtain and calculate surface-water quantity data are discussed in this section. The discussion in this section will include procedures and methods that were used to reduce the strip charts to a digital format, to obtain data from datapods and data loggers, to obtain instantaneous discharge measurements, and to develop rating curves for each station. The rating curves for each station are then used to convert the continuous stage data to daily discharge records for each station. This conversion and the validation of this data is also outlined in this section. The streamflow data collected during Water Year 1989 were for stage and instantaneous discharge. Data were collected for stage with staff gages and continuous water level recorders, and were collected for instantaneous discharge with flow meters, weirs or flumes. The gage height information will be used with rating curves which create a gage height/discharge relationship to generate daily discharge records. The instantaneous discharge measurements will be used to generate rating curves and are described in Sections 3.1.2.5 and 3.1.2.6 respectively.

3.1.2.1 Strip Chart Procedures and Equipment. The continuous monitoring stations were visited weekly to change strip charts and record staff gage measurements. Continuous water-level information was recorded on a Stevens Type F recorder attached to a float, beaded wire and pulley. The Stevens recorders are located at monitoring stations described in Table 3.1-1. During Water Year 1989 the Stevens recorders collected stage data in analog format and were collocated with either data loggers or datapods that collected data in a digital format. Weekly activities at each recording station included collecting and replacing strip charts, checking recorder operation, calibrating strip charts to the outside observed stage and initial time, and removing obstructions from stilling wells, channel sections and control structures, and checking the digital recorders. Each strip chart that was produced during Water Year 1989 was reviewed for completeness and accuracy.

The review included the following steps:

- general check on station-by-station consistency with discharge information;

- station-by-station review of outside gage height settings to ensure that they were consistent and in agreement with strip chart information and data logger information;

- review and comparison of datapod data with strip chart information;

- review of applied pen correction on a station-by-station basis; and

- correction and substantiation of observed stage information.

Due to freezing conditions at the stations, the recorders were taken out of service from late November 1988 through February 1989.

3.1.2.2 Datapod Procedures and Equipment. Five surface-water monitoring stations at RMA (North Uvalda, Ladora Weir, Peoria Interceptor, Havana Pond, and Basin A) are equipped with Omnidata International, Inc. model DP115 datapod digital recorders (Table 3.1-1). The DP115 datapod is a battery-operated, single channel, stream stage recorder. The datapod is coupled to a Stevens Type F recorder with a 10-turn potentiometer. The potentiometer receives electrical current from the datapod's power source. Movement of the recorder's pulley system varies the resistance of the potentiometer, and is recorded as a change in potential by the datapod. These changes in potential correlate to changes in stream stage.

The data provides a means of cross-checking the stage data of the Stevens strip chart for continuity and developing a digital stage record. The stage record from either the datapods or the digitized strip chart records are then used in conjunction with the established rating curves to produce daily discharge records.

The DP115 datapod recorder automatically records the date, time, and corresponding gage height on a nonvolatile solid state memory data storage module (DSM). The DSM stores at least one month of stage data. Detailed specifications and operating procedures are located in Appendix A-6.2.

The continuous monitoring stations equipped with DP115 datapods were visited weekly to obtain instrument status readouts (short dumps). Data storage modules and batteries were changed at approximately one month intervals.

3.1.2.3 Data Logger Procedures and Equipment. Four RMA surface-water stations (North First Creek, South First Creek, South Uvalda and Havana Interceptors) are equipped with Campbell Scientific CR-10 data loggers and bubbler systems (Table 3.1-1). These stations were chosen

because they can exhibit flow year round. During Water Year 1988 and in the past, collection of stage data at these stations during the freezing months when some high snowmelt flows can occur has been difficult because the float and pulley system used with the Stevens recorders freezes inside the stilling wells. The CR-10 data logger/bubbler system is used as the primary source of initial stream stage data, however, strip chart data are used to fill gaps in the data logger's record during nonfreezing months when necessary. The stage information is then used in conjunction with the established rating curves to produce daily discharge records.

The CR-10 data logger/bubbler system is a multiple channel recording instrument that can handle both analog and digital input. The bubbler system operates on the principle whereby nitrogen is fed through a tube to an orifice where the nitrogen escapes into the water. The pressure in the tube corresponds to the hydrostatic head of the water above the orifice. A transducer is used to sense the pressure in the bubbler tube. The system calibrates itself based on two different pressure measurements made at a known distance apart in a reference cylinder located in the gage house. These measurements are used to correct the measured pressure value of the CR-10's bubbler line in the stream. The data logger records all information on a 720K RAM pack storage module at 15 minute intervals. The information includes temperature, stage data, calibration data and battery voltage.

Weekly activities at the four monitoring stations equipped with the data loggers included reading staff gage water levels, measuring water depths over bubbler lines, recording instrument status readouts, and checking the bubbler systems nitrogen supply tanks. Other periodic maintenance involved monthly changing of the RAM pack storage modules, and changing of the nitrogen cylinder and battery as needed. Detailed specifications and operational procedures for the CR-10 data logger/bubbler system are located in Appendix A-6.3.

3.1.2.4 Stream Stage Data Computation. The strip chart analog stage data were reduced to a digitized format using the computer program CPSPC (Radian Corp., October 1987, Version 3.1) in conjunction with a digitizer. Surface-water flow data originally exist in analog form as a time versus gage height line chart, where the x-axis represents the time in hours and the y-axis represents the staff gage reading taken on a continuous basis. The digitizing process converts this data from analog to digital form. The digitizing tablet registers digitized points in inches, using the lower left corner of the tablet as an origin point (0", 0"). After the graph has been taped to the digitizing tablet, three reference points (upper left, upper right and lower left) are digitized. Using the keyboard, the user then associates a graph scale coordinate defining the graph location of each reference point. In this case, the scale was correlated to Julian date and scientific hours for time and to 0.01 ft for gage height.

As the user digitizes points along the line graph, they are stored in a computer file in digitizing inches. After the line has been digitized, the software program transforms the digital file into units used by the line chart graph. The transformation is done using a scale calculated from the data associated with the three reference points. For example, starting at the upper left and upper right reference points, it might be calculated that 1-in along the x-axis represents 24 hours' time. Therefore, a difference of one between the x-coordinate values of two points means that 24 hours time passed between these two readings.

This method helped reduce the strip charts to a more accurate digitized output form that was used in calculating stage-discharge relationships. The minimal digitized strip chart points chosen were 0.00, 6.00, 12.00, 18.00 and 24.00 hours for each record day. Other significant stage points selected for digitization were high flow events, when gage heights were digitized at a minimum of 15 minute intervals, and any stage points that exhibited 0.1+ ft of deflection within any 2 hour period. Finally, the digitized stage output was compared to the strip chart analog record and corrected to the observed staff gage settings. Problem areas noted in this process included insufficient digitized points being recorded to characterize the gage height record, particularly during high flow events, and incorrect pen adjustments. For periods of no record (when equipment may have malfunctioned), the gaps were filled in by estimating the stage or supplementing with datapod or data logger data. This estimated part of the record was extrapolated from the week's beginning and ending staff gage readings. The estimated values are noted in the remarks section of the water-discharge record in Appendix A-8.1.

The digital datapod records were not utilized for this report. The collection of datapod records was used primarily to assess the feasibility using the datapods and developing procedures for future datapod collection. The digital data logger stage record is downloaded from the RAM pack storage module to a computer. The data logger stage data was used primarily and supplemented with Stevens recorder stage data. Details of the stage data process are in Appendix A-6.

3.1.2.5 Discharge Measurement Procedures and Computation of Discharge Data. Discharge is defined as the volume rate of water flow and is expressed in cubic feet per second (cfs). Discharge measurements were made on a monthly basis at active stations for the seasonal surface-water quantity monitoring, with additional measurements being made at high surface-water flow events and during the spring and fall sampling events. In addition to the scheduled monthly measurements, instantaneous discharge measurements were obtained whenever unusual flow conditions were observed. Discharge measurements were made using standard U.S. Geological Survey (USGS) monitoring techniques (Rantz, 1982). Low to moderate flow measurements were made with a

Teledyne-Gurley Pygmy current meter, a Marsh-McBirney Model 201 current meter with top-setting wading rod, or 100 mm and 200 mm long-throated flumes (Appendix A-2.2). Higher flows were measured with a Price Type-AA current meter with top-setting wading rod. All meter measurements were wading measurements, i.e., the hydrographer waded into the stream to collect the flow observations. Indirect measurements were made that involved surveying stream channel cross sections and stream slopes using Hydrologic Engineering Center (HEC-2) computer analysis (U.S. Army Corps of Engineers, 1982). This analysis was used to extend the upper and lower limits of the rating curves.

Each measurement was taken at the most desirable stream cross section monitoring stations. The stream cross section was chosen according to the following criteria:

- a straight reach where flow components parallel each other (laminar flow);
- a stable stream bed, free of large rocks, weeds and protruding obstructions, such as piers and posts, which cause turbulence;
- a flat stream bed profile to eliminate vertical components of velocity; and
- a section having uniform velocity distribution (i.e., avoiding ponded areas), where flow would be similar across the entire section (for meter measurements).

For the shallow streams typically found at RMA, stream depths and flows were generally measured using a top-setting wading rod and a current meter appropriate for the stream flow conditions encountered. When the average depth of flow exceeded 1.5 ft (high flow) the Price Type-AA current meter generally was used. If the average depth of flow was less than 1.5 ft but greater than 0.3 ft (low to moderate flows), then a Pygmy current meter was used. The Marsh-McBirney current meter was used sparingly as a backup to the Type-AA and Pygmy Meters. As a safety measure, if the depth of flow multiplied by the velocity exceeded 10 ft/sec, then wading techniques were not undertaken. A portable, 200 mm long-throated flume was put into use during April 1989 and a 100 mm long-throated flume was put into use in June 1989. Discharges ranging from 0.0078 cfs to 0.3099 cfs are obtainable with the 100 mm flume and discharges of 0.0367 cfs to 1.762 cfs are measurable with the 200 mm flume.

Calibration checks were performed on each meter prior to the start of the current meter measurements at each site. The calibration checks for the Pygmy and Type-AA current meters (which both have a vertical shaft and rotating cups), are detailed in Appendix A-2.2. Field

procedures implemented to measure and calculate current meter instantaneous discharge are detailed in Appendix A-2.2. The procedures that were followed to measure discharge rates using the portable flumes are also detailed in Appendix A-2.2.

3.1.2.6 Rating Curve Development Procedures. Continuous records of discharge at the RMA gaging stations are computed by applying a discharge rating for each stream location to records of stage. Discharge ratings for the RMA stations are typically curves plotted on logarithmic paper that relate stage to discharge (Appendix A-3.2 and A-3.3). These curves are also described mathematically by the use of rating equations (Appendix A-4). The stage-discharge relationships (rating curves) for the new RMA gaging stations, or existing stations with modified control structures, were determined empirically by means of periodic measurements of discharge and stage. This information was evaluated in conjunction with a theoretical analysis using information on channel geometry (Appendix A-1). The discharge measurements were usually made with a current meter or portable structure, as described in the previous section. For ranges in stage where empirical measurements were not available, theoretical stage-discharge relationships were computer-generated using measurements of cross section and reach geometry (HEC-2 analysis). The new gaging stations or stations with a modified section control that required a stage-discharge relationship to be developed this year included:

- Peoria Interceptor (SW11001) - modified control structure
- South First Creek (SW08003) - new station
- North First Creek (SW24002) - new station
- First Creek Off-Post (SW37001) - new control structure

For those gaging stations on the RMA which have previously defined rating relationships, periodic measurements of discharge and stage were used to confirm the permanence of the rating and/or to follow changes (shifts) in the rating. Shifts in the discharge rating reflect the fact that stage-discharge relationships are not permanent but vary from time to time, either gradually or abruptly, because of changes in the physical features that form the control for the station.

Following the review, verification and validation of instantaneous discharge measurements valid measurements were plotted to determine if the rating used for the previous water year was applicable for part or all of the present water year. This information is summarized in Appendix A-5. Discharges computed from the previous rating were compared to current water year

instantaneous discharges. Percentage differences between measured and computed discharges were calculated. As long as the departures were random in sign and within ±5 percent, the previous rating was kept in effect and used to convert 1989 water year continuous stage data to discharge (Rantz, 1982). For low-flow measurements, the ±5 percent criteria is sometimes too stringent because of station control insensitivity; therefore, stage departures were calculated for low flow measurements using the same methodology as used to calculate discharge departures. If the indicated departures in stage did not exceed ±0.02 feet, the previous rating was kept in effect (Rantz,1982). The gaging stations on the RMA that required confirmation and/or shifts of previously defined stage-discharge relationships included:

- Havana Interceptor (SW11002)
- Ladora Weir (SW02001)
- South Uvalda (SW12005)
- North Uvalda (SW01001)
- Highline Lateral (SW12007)
- South Plants Ditch (SW01003)
- Basin A (SW36001)

The relationship of stage to discharge is usually controlled by a section or reach of channel known as a station control and is located immediately downstream from a gage. Station controls at RMA are divided into three types: channel control, section control and compound control. Channel control exists when the physical features of a long reach of channel are the elements that control the stage-discharge relationship. Section control can be artificial or natural, but must have physical features such as a weir, flume or rock ledge outcrop, within a single cross section that maintains a stable relationship between stage and discharge. A compound control is a situation where no single control is effective for the entire range of experienced stages. Compound controls typically exhibit section control at lower stages and channel control at medium to high stages as section control features become submerged (Rantz, 1982).

The types of station control found at respective RMA gaging stations include:

- Channel Control
  - Havana Interceptor - concrete lined channel

- Section Control
  - Highline Lateral - Cipolletti weir
  - Ladora Weir - standard suppressed rectangular weir
  - Basin A - 90° V-notch weir
  - First Creek Off-Post - concrete triangular-throated flume
  - South Plants Ditch - 90° V-notch weir
  - South First Creek - concrete V-notch weir
  - North First Creek - concrete V-notch weir

- Compound Control
  - South Uvalda - compound V-notch weir
  - North Uvalda - compound V-notch weir
  - Peoria Interceptor - compound weir with a 90° V-notch and standard contracted rectangular weir

A detailed description of the methodology used in determining the stage-discharge relationship for each of the gaging stations on the RMA is presented in Appendix A-3.1.

3.1.2.6.1 Conversion of Stream Stage to Discharge. - A computer program was used to convert gage height data to instantaneous and daily average discharges, and to produce formatted summaries of the discharge records. The program steps are as follows:

- The first step of the process is to check the time and date of each gage height value to select the rating equations, shifts, and/or adjustments corresponding to the respective time period. The magnitude of each gage height value is then compared with the valid range of each rating equation so that the appropriate equation is selected.

- Next, the program computes a discharge for each of the gage height values occurring on a given day using the selected rating equations of the general forms previously defined, and delineated in Appendix A-3.

- Each daily discharge data set is time weighted and summed to obtain the daily average using the formula:

$$Q_a = \frac{1}{24} \sum_{i=1}^{n} \frac{(t_i + 1) - (t_i - 1)}{2} Q_i$$

where

Q_a = average daily discharge (cfs);

n = number of gage height entries for a given day;

t_i = twenty-four hour time in hours corresponding to gage height entry i; and

Q_i = discharge corresponding to gage height entry i (cfs).

This process is repeated for each day in the record.

- Finally, the monthly totals and averages are calculated from the daily averages, and the results are formatted for printing.

3.1.2.6.2 Channel Reach Surveys. - Channel cross section surveys were conducted at RMA gaging stations that did not have laboratory-rated structures to provide section control for the complete range of stages being monitored. Channel cross section surveys were acquired at the North First Creek gaging station (SW24002) to support a theoretical high-flow extrapolation of the stage-discharge rating relationship, during Water Year 1989. Five cross sections were surveyed: one channel cross section was surveyed below the concrete structure, one cross section through the center of the concrete structure, and three additional cross sections upstream of the concrete structure.

During Water Year 1988 cross section surveys were conducted at four additional monitoring sites. Six cross sections were surveyed at South Uvalda (SW12005) and at Peoria Interceptor (SW11001). Additionally, North Uvalda (SW01001) had four cross sections surveyed and Havana Interceptor (SW11002) had one cross section surveyed. A detailed description of the procedure used in conducting the channel reach surveys is presented in Appendix A-1.2.4. Channel reach survey data is presented in Appendix A-1.2.3.

3.1.2.7 Related Surface-Water Data Acquisition. Warning of major rainfall-runoff events was obtained from a meteorological contractor who forecasted storm events on a daily basis for the Stollar team and identified the location of storm activity. This system was used for the acquisition of storm (high event) sampling and high flow instantaneous discharge measurements.

Precipitation and temperature data for the 1989 water year were obtained from Stapleton Airport on a daily basis and CMP Air Element. Evaporation data were compiled as a monthly average based on information collected at Cherry Creek Reservoir.

Physical data on the lakes were collected by direct measurement of staff gages, which were monitored on a weekly basis. The weekly observed staff gage readings of the South Plants Lakes and Havana Pond were converted to elevation in feet above mean sea level (ft-msl) and correlated to volume in acre-feet (ac-ft) as determined from previous surveys by Hunter/ESE (Ebasco Services, Inc., 1989; Appendix B). Lake/pond volumes were based on this information and were calculated on a monthly basis using a refined volume relationship. The stage and elevation relationships as determined by previous contractors did not correlate with the recently resurveyed CMP information. For this reason, the elevation and volume relationship, as determined by previous contractors, was used to compute the volumes of the South Plants Lakes and Havana Pond. Additionally, Havana Pond data were also collected by a Stevens Type F recorder in conjunction with a potentiometer and DP115 datapod. The Havana Pond continuous record was reduced in the same manner as described in Section 3.1.2.4.

All water-level monitoring stations and sampling stations were surveyed by Itech Survey during Water Year 1988 and any changes to the network were resurveyed during Water Year 1989. TBMs were established at each water level monitoring station. Elevations of staff gages, weirs, TBMs and sample locations were established at each site. Northing and Easting coordinates were also surveyed and computed for each of the water-level monitoring stations and sample locations. This information is contained in Appendices A-1.1 and B-1.

3.1.3 South Uvalda Stage Record Review Procedures

The objectives of this review were to determine: (1) if historical strip charts for the period October 1985 through September 1987 were accurately reduced; and (2) if the resulting records were accurately converted to discharge record.

An initial examination of historical strip charts indicated that historical data reduction methods were consistent for all of the continuous stage recording stations, and that any significant errors in these methods discovered at one station would be applicable to all stations. Therefore, the most efficient approach to the historical review was to conduct a re-analysis of strip charts, stage and discharge records for a single station.

The South Uvalda (SW12005) gaging station record were selected for re-analysis because:

- These records are very important to the CMP, since the South Uvalda gaging station is located on one of the more significant drainages conveying flow onto the RMA;

- South Uvalda flow is significantly affected by urban runoff, which results in large peak events, rapid fluctuation in flow, and longer periods of sustained flow; and

- Historical inaccuracies in record keeping, data reduction, and rating relationships are more easily identifiable at a station experiencing the previously described flow-regime variability.

The South Uvalda gaging record review involved both a preliminary and a subsequent detailed analysis of the gaging records from October 1985 through September 1987. The preliminary analysis involved the following procedures:

- Strip charts were checked for continuity between starting and ending times and stage notations with respect to the trace on the strip chart;

- Baseline shifts were identified;

- Strip charts were checked for errors, missing notation, and equipment malfunctions;

- Strip charts and field notes were reviewed to identify periods of questionable stage records caused by changes in the channel condition (e.g., debris in control structure); and

- Strip charts were reviewed to identify periods of missing or inaccurate record.

Initially the preliminary analysis evaluated eight (8) strip charts that represented seasonal flow extremes, including steady base flow periods and periods of rapidly fluctuating flow. If obvious errors in chart annotation and data reduction methods were identified in this group, the credibility of all historical gaging records would be questionable.

Since no significant problems were encountered in the preliminary analysis of the initial eight strip chart, a more detailed analysis was conducted on all the records for South Uvalda. The detailed analysis phase included the following:

- The preliminary analysis (as described above) was conducted on all charts;

- All charts were digitized to support a detailed comparison of digitized stage records to the historical records that were generated using a manual, non automated method;

- The historical stage record, which was originally generated manually to the nearest 0.05 ft, was compared to the newly digitized records. This included:

  - comparison of the magnitude of the instantaneous peak stages;

  - comparison of the timing of the instantaneous peak stages; and

  - general comparison of all stage data.

- The historical discharge records were compared to the newly computed discharge records. The new discharge records were prepared by applying the most current applicable 1989 water year rating curve to the newly digitized stage record. This comparison included:

  - monthly instantaneous minimum and maximum discharges;

  - minimum and maximum daily mean discharges; and

  - total monthly flow volumes in acre-feet (ac-ft).

3.2 Surface-Water Quality

This section will detail surface-water quality sampling and analytical procedures and strategies that were used for the spring, storm and fall 1989 sampling events at RMA on- and off-post sample locations. The surface-water quality sample locations and sampling frequencies are presented in this section. Plate 1.3-2 shows the locations of each surface-water quality sampling location within the major RMA drainage basins. Also outlined in this section are water-quality sampling and analytical procedures (conducted in accordance with PM/RMA/USATHAMA requirements for sample collection), sample preservation, sample shipment, sample analysis, and chain-of-custody.

3.2.1 Surface-Water Quality Monitoring Network

Under the CMP, sample locations were selected primarily from the network established in the Task 44 study, supplemented with some new locations. The CMP sample locations relative to RMA drainage basins are illustrated in Plate 1.3-2. Task 44 sample locations were incorporated along with location adjustments established during FY88 because it was important to maintain the established network so that the surface-water quality baseline could be verified continuously. Surface-water quality monitoring during Water Year 1989 was considered at thirty-five locations. Sampling was considered at all of the surface-water quantity stations as described in Section 3.1 if water existed at the station. Surface-water quality samples that were obtained during Water Year 1989 included 17 locations in Irondale Gulch Drainage Basin, ten locations in First Creek Drainage Basin, one location in Sand Creek Drainage Basin and one location in South Platte Drainage Basin (Table 3.2-1). Sampling sites located at water quantity monitoring stations are described in Section 3.1, and other sampling locations within the drainage basins are described in Section 2. A summary of Water Year 1989 sampling frequency relative to RMA drainage basins is presented in Table 3.2-1.

3.2.2 Surface-Water Quality Monitoring Strategies

Water-quality samples were analyzed for the parameters listed in Table 3.2-2 for this second year of the Surface-Water CMP. Most water samples were analyzed for the target analytical suite of parameters because of the uncertain characterization of surface-water quality at RMA and for use in a comparison to the ground-water quality.

Data collected during previous surface-water monitoring programs (Section 1.3) indicated that organic contaminants may have been derived from off-post sources south of RMA that moved onto and across RMA through surface-water pathways. The suite of target analytes listed in Table 3.2-2 may not be sufficiently comprehensive to include such contaminants. Consequently, the target analyte list was supplemented by gas chromatography and mass spectroscopy (GC/MS) analysis of selected samples. The sampling and analytical procedures employed in this program are discussed in more detail below and in Appendix B.

Plate 1.3-2 illustrates the sample locations that were considered for this CMP year. Table 3.2-1 summarizes the frequency of water-quality sampling accomplished during Water Year 1989. A total of 49 samples were collected from 29 sample locations between spring and fall of 1989. In addition, seven samples were collected at seven stations during three different storm events. Most of the sampling activities (excluding storm events) were conducted in conjunction with discharge measurements.

Table 3.2-1 Water Year 1989, Summary of Sampling Activities

Sample Location Number	Location Name	Site Type	Sampling Frequency		Analysis: Target	Analysis: GC/MS	Analysis: Bottom Sediments	Analysis: Quality Assurance
Irondale Gulch Drainage Basin								
SW01001	North Uvalda Interceptor	Ditch	Spring Fall	4/27/89 9/26/89	1	1	1	1,(trip/GC/MS)
SW01002	South Plants Water Tower Pond	Pond	Annual	5/18/89	1	1	1	
SW01003	South Plants Ditch	Ditch	Spring Fall	Dry Dry				
SW01004	Upper Derby Lake	Lake	Annual	4/19/89	1			
SW01005	Lower Derby Lake	Lake	Annual	4/18/89	1 (dupe)			
SW02001	Ladora Weir	Ditch	Annual	Dry				
SW02002	Sand Creek Lateral East	Ditch	Annual	Dry				
SW02003	Ladora Lake	Lake	Annual	4/18/89	1	1		1 (rinse)
SW02004	Lake Mary	Lake	Annual	4/19/89				
SW02005	Sand Creek Lateral West	Ditch	Annual	Dry				
SW02006	South Plants Steam Effluent	Stream	Spring Fall	4/27/89 9/27/89	1 1	1 1	1 1	

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Table 3.2-1 Water Year 1989, Summary of Sampling Activities (continued)

Sample Location Number	Location Name	Site Type	Sampling Frequency		Analysis: Target	Analysis: GC/MS	Analysis: Bottom Sediments	Analysis: Quality Assurance
SW24004	First Creek North Boundary	Stream	Annual	4/29/89	1			
SW30001	North Plants	Ditch	Annual	Dry				
SW30002	First Creek near North Plants	Stream	Annual	4/29/89	1		1	
SW31001	First Creek Toxic Yard A	Stream	Annual	4/25/89	1		1	
SW31002	First Creek Toxic Yard B	Pond	Annual	4/25/89	1		1	
SW37001	First Creek Off-Post	Stream	Spring	4/20/89	1	1	1	
South Platte Drainage Basin								
SW36001	Basin A	Ditch	Spring	4/28/89	1	1	1	
			Fall	9/28/89	1	1	1	2 (field, trip)Storm
Sand Creek Drainage Basin								
SW04001	Motor Pool	Ditch	Annual	Dry				
			Storm	5/15/89				
			Annual Total		13	5	6	Rinse Tot. 1
			Spring Total		13	10	11	Field Tot. 2
			Storm Total		7	4	0	Trip Tot. 2
			Fall Total		12	7	5	
			Dupe Total		4	3	3	
			TOTAL		49	29	25	5

GC/MS = Gas Chromatograph/Mass Spectrometer
Dupe = Duplicate Sample Taken
Stp = Sewage Treatment Plant

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Table 3.2-1 Water Year 1989, Summary of Sampling Activities (continued)

Sample Location Number	Location Name	Site Type	Sampling Frequency		Analysis: Target	GC/MS	Bottom Sediments	Quality Assurance
Irondale Gulch Drainage Basin (continued)								
SW12002	Uvalda Ditch D	Ditch	Annual	Dry				
			Storm	5/15/89	1			
SW12003	Rod & Gun Club Pond	Pond	Annual	4/20/89	1		1	
SW12004	Storm Sewer	Stsw	Spring	4/19/89	1		1	
			Fall	9/26/89	1			
SW12005	South Uvalda	Stream	Spring	4/17/89	1	1	1	
			Storm	5/10/89	1	1		
			Fall	9/26/89	1	1	1	
SW12007	Highline Lateral	Ditch	Annual	Dry				
First Creek Drainage Basin								
SW08001	South First Creek Boundary	Stream	Annual	4/25/89	1	1	1	
SW08003	South First Creek	Stream	Spring	4/25/89	1		1	
			Stream	5/14/89	1	1		
			Fall	9/26/89	1 (dupe)	1 (dupe)	1 (dupe)	
SW24001	Sewage Treatment Plant	Stp	Spring	4/21/89	1 (dupe)	1 (dupe)		
			Fall	9/27/89	1	1		
SW24002	North First Creek	Stream	Spring	4/21/89	1	1	1 (dupe)	
			Storm	5/15/89	1			
			Fall	Dry				
SW24003	North Bog	Lake	Annual	4/21/89	1	1		

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Table 3.2-1 Water Year 1989, Summary of Sampling Activities (continued)

Sample Location Number	Location Name	Site Type	Sampling Frequency		Analysis			
					Target	GC/MS	Bottom Sediments	Quality Assurance
SW07001	Uvalda Ditch A	Ditch	Spring	4/27/89	1	1	1	
			Fall	9/25/89				
SW07002	Uvalda Ditch B	Ditch	Spring	Dry				
			Fall	9/25/89	1			
SW11001	Peoria Interceptor	Ditch	Spring	4/26/89	1 (dupe)	1 (dupe)	1 (dupe)	
			Storm	5/10/89	1	1		
			Fall	9/27/89	1	1	1	
SW11002	Havana Interceptor	Ditch	Spring	4/26/89	1	1	1	1 (field/GC/MS)
			Storm	5/10/89	1	1		
			Fall	9/27/89	1	1		
SW11003	Havana Pond	Pond	Annual	4/25/89	1	1		
SW12001	Uvalda Ditch C	Ditch	Spring	4/20/89	1			
			Fall	9/25/89	1			

Table 3.2-2 DataChem and ES&E Laboratories Analytical Methods for Water Sediment Samples

Analyte Suite	Parameters	Lab.	Method* Number	Water (µg/l) Reporting Limits (min.)	(max.)	Lab.	Method* Number	Soil (µg/g) Reporting Limits (min.)	(max.)
Volatile Aromatics	Benzene	DC, ESE	AV8	1.05	40.2	DC, ESE	AA9	.085	5.0
	Toluene			1.47	39.7			0.19	2.0
	Chlorobenzene			1.39	39.8			-	-
	Ethylbenzene			1.37	39.7			0.16	10.0
	1,3-Xylene			1.32	39.9			0.26	5.0
	1-2-Xylene			1.36	39.6			0.39	2.0
Volatile Halocarbons	1,1-Dichloroethane	DC, ESE	N8	1.70	200	DC, ESE	NN9	0.24	5.0
	1,1-Dichloroethane			0.73	200			0.074	5.0
	1,2-Dichloroethane			0.76	200			0.26	5.0
	Chloroform			0.50	200			0.068	5.0
	1,2-Dichloroethane			1.10	200			0.85	5.0
	1,1,1-Trichlorethane			0.760	200			0.088	5.0
	Carbon Tetrachloride			0.990	200			0.12	5.0
	1,1,2-Trichloroethane			0.780	200			0.26	10.0
	Tetrachloroethane			0.750	200			0.14	10.0
	Chlorobenzene			0.750	200			0.20	10.0
	Methylene Chloride			7.40	200			3.70	10.0
DBCP	1,2-Dibrommo-3-chloropropane	DC, ESE	AY8	0.195	10	DC, ESE	S9	0.005	0.10
Organosulfur compounds	Dimethyldisulfide	DC, ESE	AAA8	0.55	15	DC, ESE	HH9A	3.12	20.0

* Description of Method in Appendix B
DC = DataChem Laboratory
ESE = Hunter/ESE

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Table 3.2-2 DataChem and ES&E Laboratories Analytical Methods for Water Sediment Samples (continued)

Analyte Suite	Parameters	Lab.	Method* Number	Water (µg/l) Reporting Limits (min.)	Water (µg/l) Reporting Limits (max.)	Lab.	Method* Number	Soil (µg/g) Reporting Limits (min.)	Soil (µg/g) Reporting Limits (max.)
	1,4-Oxathiane			2.38	25			1.74	10.0
	1,4-Dithiane			1.34	25			1.45	20.0
	Benzothiazole			5.00	50			4.40	20.0
	p-Chlorophenylmethyl sulfide			5.69	50			4.40	20.0
	p-Chlorophenylmethyl sulfoxide			11.5	75			4.81	20.0
	p-Chlorophenylmethyl sulfone			7.46	100			9.01	40.0
Organochlorine Pesticide	Hexachlorocyclopentadiene	DE, ESE	KK8	0.048	0.99	DC, ESE	KK9B	0.0014	0.040
	Aldrin			0.050	1.00			0.0021	0.040
	Isodrin			0.051	1.10			0.0019	0.040
	PPDDE			0.054	1.0			0.0047	0.040
	Dieldrin			0.050	1.0			0.0018	0.040
	Endrin			0.050	1.0			0.0047	0.040
	PPDDT			0.049	1.0			0.0028	0.040
	Chlordane			0.095	1.0			0.023	0.400
Hydrocarbons	Bicycloheptadiene	DC, ESE	P8	5.90	104.2	DC, ESE	PP9	1.10	10.2
	Dicyclopentadiene			5.00	99.6			0.45	9.0
	Methylisobutyl Ketone			4.90	98.0			0.64	10.4
Anions	Bromide	DC, ESE	HH8A	-	-	DC, ESE	HHH9	-	-
	Chloride			716.0	10,000			14.00	200

* Description of Method in Appendix B
DC = DataChem Laboratory
ESE = Hunter/ESE

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Table 3.2-2 DataChem and ES&E Laboratories Analytical Methods for Water Sediment Samples (continued)

Analyte Suite	Parameters	Lab.	Method* Number	Water (μg/l) Reporting Limits (min.)	Water (μg/l) Reporting Limits (max.)	Lab.	Method* Number	Soil (μg/g) Reporting Limits (min.)	Soil (μg/g) Reporting Limits (max.)
	Fluoride			480.0	5,000			10.00	100
	Sulfate			250.0	10,000			88.00	1,000
Nitrate	Nitrate	DC, ESE	LL8	10.0	200	-	-	-	-
Arsenic	Arsenic	DC, ESE	CC8	0.1	2.0	DC, ESE	Y9	2.5	50.0
Mercury	Mercury	DC, ESE	CC8	0.1	2.0	DC, ESE	Y9	0.05	1.0
ICP Metals	Cadmium	DC, ESE	SS12	6.8	12,5000	DC, ESE	P9	0.74	50.0
	Chromium			16.8	1,000			6.5	50.0
	Copper			18.8	10,000			4.7	50.0
	Lead			43.4	10,000			8.4	50.0
	Zinc			18.0	10,000			8.7	50.0
	Magnesium			135	100,000			-	-
	Calcium			105	100,000			-	-
	Sodium			279	100,000			-	-
	Potassium			1240	10,000			-	-
Volatiles	1,1,1-Trichloroethane	DC, ESE	UM21	1.0	100	DC, ESE	LM23	0.43	10.0
	1,1,2-trichloroethane			1.0	100			0.39	25.0
	1,1-Dichloroethane			1.0	150			1.7	25.0
	1,1-Dichloroethane			1.0	150			-	-
	1,2-Dichloroethane			1.0	150			0.56	5.0
	1,2-Dichloroethane			5.0	150			-	-

* Description of Method in Appendix B
DC = DataChem Laboratory
ESE = Hunter/ESE

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Table 3.2-2 DataChem and ES&E Laboratories Analytical Methods for Water Sediment Samples (continued)

Analyte Suite	Parameters	Lab.	Method* Number	Water (µg/l) Reporting Limits (min.)	Water (µg/l) Reporting Limits (max.)	Lab.	Method* Number	Soil (µg/g) Reporting Limits (min.)	Soil (µg/g) Reporting Limits (max.)
	Benzene			1.0	150			0.25	25.0
	Carbon Tetrachoride			1.0	100			0.25	10.0
	Chlorobenzene			1.0	150			1.5	10.0
	Chloroform			1.0	150			0.29	5.0
	Ethyl Benzene			1.0	150			0.38	25.0
	Methylene Chloride			1.0	150			1.5	25.0
	Tetrachloroethene			1.0	150			0.25	25.0
	Toluene			1.0	150			0.25	25.0
	Trichloroethane			1.0	150			0.54	25.0
	1,3-Dimethylbenzene			1.0	150			0.74	10.0
	Xylene			2.0	300			4.9	50.0
	Methylisobutyl Ketone			1.4	100			0.73	25.0
Semi-volatiles	Aldrin	DC, ESE	UM25	13	300	DC, ESE	L9	0.30	99.5
	Atrazine			5.9	300			0.30	99.5
	Hexachlorocyclopentadiene			54	300			0.60	25.1
	Chlordane			37	300			2.0	25.1
	p-Chlorophenylmethyl sulfide			10	300			0.90	99.5
	p-Chlorophenylmethyl sulfoxide			5.3	300			0.30	99.5
	p-Chlorophenylmethyl sulfone			15	300			0.30	99.5
	Dibromochloropropane			12	300			0.30	99.5
	Dicyclopentadiene			5.5	300			1.0	50.0
	Vapona			8.5	300			3.0	99.5
	Diisopropylmethyl Phosphonate			21.0	200			3.0	99.5
	Dithiane			3.3	100			0.40	99.5

* Description of Method in Appendix B
DC = DataChem Laboratory
ESE = Hunter/ESE

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Table 3.2-2 DataChem and ES&E Laboratories Analytical Methods for Water Sediment Samples (continued)

				Water (μg/l)				Soil (μg/g)	
				Reporting Limits				Reporting Limits	
Analyte Suite	Parameters	Lab.	Method* Number	(min.)	(max.)	Lab.	Method* Number	(min.)	(max.)
	Dieldrin			26.0	100			3.30	99.5
	Dimethylmethyl Phosphate			130	200			-	-
	Endrin			18	200			0.30	25.1
	Isodrin			7.8	300			0.30	25.1
	Malathion			21.0	300			0.70	25.1
	Oxathiane			27.0	300			0.30	99.5
	PPDDE			14.0	300			0.60	50.0
	PDDT			18.0	100			0.47	25.1
	Parathion			37	300			0.90	25.1
Cyanide	Cyanide	DC, ESE	TF20	5.0	200				
Nitrogen/ Phosphate Pesticides	Atrazine	DC, ESE	UH11	4.03	100				
	Parathion			0.647	50				
	Malathion			0.500	50				
	Supona			0.787	50				
	Vapona			0.500	50				

* Description of Method in Appendix B
DC = DataChem Laboratory
ESE = Hunter/ESE

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3.2.3 Surface-Water Quality Monitoring Field Methods

Specific collection or monitoring methods are described in the Stollar "Surface-Water Field Procedures Manual II" (Stollar, 1988). The manual contains certification procedures and laboratory data forms. All collection procedures and analytical methods complied with the USATHAMA Quality Assurance Program (U.S. Army, Chemical QA Plan, 1989).

Stream samples were obtained by integrating samples collected over the cross sectional area of the stream at a depth of 1 to 4 inches. Where the stream was too small to permit this, the samples were collected from the center of the channel just below the stream surface, at a depth of 1 to 4 inches. Lake or pond samples were collected as grab samples from near the shoreline.

Parameters measured in the field included pH, electrical conductivity, alkalinity, and dissolved oxygen; however, during the fall sampling round, alkalinity and dissolved oxygen were excluded. The field instruments were calibrated with known standards.

Surface-water samples were collected with a stainless steel bucket, a clean sample container, or if appropriate, directly with the sample bottle. Samples for organic analysis (VOA, DBCP, DCPD, organochlorines and organosulfurs) were collected in amber glass bottles with Teflon (R) - lined caps. Samples for inorganic analysis (chloride and fluoride, total metals-unfiltered and nitrates) were collected in polyethylene containers. Dissolved metals fractions were filtered in the field using 0.45 micron nitrocellulose acetate filters, however, metals samples were not filtered in the field during the fall 1989 sampling round. Metals fractions were fixed with dilute nitric acid to a pH of 2. The nitrates fraction was fixed with dilute sulfuric acid to a pH of 2. All sample bottles were placed on ice in a sample cooler immediately upon filling. Bed load sediment samples were collected directly into 8 oz wide mouth jars.

In order to characterize the influence of contaminants on water chemistry, originating at RMA it was necessary first to determine the quality of water entering RMA. For this reason, gas chromatography-mass spectroscopy (GC/MS) (EPA 624/625) analyses were performed (in addition to analyses for target parameters) on surface-water samples collected on all inflows near the southern and southeastern boundaries of the property, and on the single outflow of First Creek near the northern boundary (Table 3.2-1). The GC/MS method confirms contaminant levels detected by other methods and is capable of indicating the presence of nontarget compounds. In addition, GC/MS analysis was performed on approximately 59 percent of the samples collected from the remaining sites located within RMA. These samples were selected on the basis of historical monitoring and field conditions.

3.2.4 Laboratory Analytical Procedures for Water and Sediments

Table 3.2-2 presents method names with corresponding method numbers and reporting limits for the analyzed parameters. The discussion in Appendix B-7 gives a brief method summary of each of the analytical methods from DataChem Laboratories and Hunter/ESE Laboratories used for the chemical analysis of surface water and stream sediment samples.

3.2.5 Laboratory Quality Control Data

3.2.5.1 Water Quality and Sediment Analytical Assurance and Quality Control. Accuracy and precision of the analytical measurement process is continually monitored by analyzing spikes and surrogates with each sample lot. Accuracy is assessed by statistically evaluating recovery data from analyses of the spikes and surrogates. A three-day moving mean is calculated and plotted on the control charts for each spike or surrogate. Out-of-control situations may be indicated by:

- a value outside the control limits
- a value classified as an outlier by statistical testing
- a series of seven consecutive points on one side of the mean
- a series of five successive points going in the same direction and
- two consecutive points between the upper warning limit and upper control limit, or the lower warning limit and lower control limit.

When one of the above conditions is indicated on the control chart, an investigation is conducted to determine the cause and provide corrective action. This investigation may indicate that control analysis, reanalysis or resampling may be required for part of all analyses associated with that quality control sample. If the quality control data are within control, the data are reported to the database and accuracy corrections applied.

Precision is assessed by developing range control charts from the difference between the recovery percentages for the two spiked quality control samples in each lot. Out-of-control situations may be indicated by:

- a value above control limit
- a value considered as an outlier by statistical testing
- a series of five consecutive points going in an upward direction
- a cyclical pattern of control values or

- two consecutive points between the upper warning limit and upper control limit.

Laboratory investigations are conducted as described in the discussion of accuracy control charts, if indicated by the above conditions. Quality Control results are presented in Section 4.5.

Method blanks are analyzed with each lot of samples to monitor potential sample contamination from laboratory sources. Method blank results greater than two times the analyte detection limit are subtracted from the sample results.

3.2.5.2 Suspended Sediment Analysis Quality Assurance and Quality Control. Daily calibration checks are performed for each balance used for weighing. Records for these checks are maintained in a logbook kept with the balance. If the calibration check results vary from the standard weight of 100 mg, the balance is recalibrated. Periodic recalibrations are also performed by the manufacturer. Duplicate analysis was conducted on one of the sediment samples. Identical weights were obtained from the sample and duplicate.

3.3 Sediment Transport

Contaminants in RMA surface-water may have a pathway through sediment transport. Sediment loading in the RMA drainages influences both the aquatic habitat and channel evolution of the channels. As a result of construction and remedial activities, increased loading of the streams has significantly modified the characteristics of the drainages (e.g., silting) and resulted in sediments being deposited on to and downstream of RMA. This section will present the methods and procedures used to obtain sediment quantity and quality data during Water Year 1989. The purpose of this exercise was to:

- evaluate sampling equipment and methodology;
- evaluate the bottom sediment quality; and
- access suspended sediment quantity along a portion of First Creek.

3.3.1 Scope of Investigation

Contaminants may be transported through the surface-water system by adsorption onto sediment particles that move in the drainages as suspended or bed load particles. Limited data exist to evaluate the magnitude of the flow of low solubility contaminants such as heavy metals, pesticides, and semi-volatile organics. As a result of the potential importance of sediment transport and the limited amount of available information, a program was developed and initiated during Water Year

1988 and continued during Water Year 1989. The program during Water Year 1989 included suspended sediment sampling along First Creek in Section 8 for sediment quantity analysis and sampling bed load or bottom sediments throughout RMA at various surface-water quality sampling locations (Table 3.2-1). The objectives of the program included:

- obtaining additional baseline sediment quantity data on the transport of suspended sediments in First Creek; and

- analyzing bed load sediments to track the quality and identity of any adsorbed contaminates.

3.3.1.1 Sediment Quantity. In order to obtain information on the suspended sediment load of First Creek, samples were collected and analyzed for total suspended solids (TSS). Three sampling locations were chosen along First Creek, going from the southern boundary of RMA in Section 8 to 6th Avenue also in Section 8 where First Creek flow ended during the sampling period. Plate 1.3-2 illustrates the selected sample locations (SW08001, SW08003 and SW08004). Suspended samples were collected on September 29, 1989 at each location to assess the sampling equipment, the sediment quantity (by determining TSS) and the sampling scheme. Discharge measurements were also collected at the time of sample collection.

3.3.1.2 Sediment Quality. A second objective of this program was to evaluate the significance of bed load sediments as a mechanism for the transport of adsorbed contaminants. Consequently, samples of bed load sediments were retained for chemical analysis. The procedures used in the collection, handling and shipment of these samples are detailed in the CMP "Surface-water Field Procedures Manual". The methods and target analytes that were used are detailed in Table 3.2-2.

3.3.2 Sediment Strategy and Methods

Suspended sediment samples were collected using a hand-held, depth-integrating sampler, model DH-48, made by Scientific Instruments and described in detail by Guy and Norman (1970). Samples were collected in the DH-48 from the middle of the creek over a period of ten minutes. Suspended sediment quantitative procedures are described in Appendix B-7. Bed load or bottom sediment materials for chemical analysis were collected directly into the sample container. A total of 11 bed load sediment samples were collected during the spring of Water Year 1989 and a total of 5 bottom sediment samples were obtained during the fall 1989 sampling round. Bottom sediment samples were collected at locations outlined in Table 3.2-1 and were analyzed for the parameters listed in Table 3.2-2.

3.4 Ground-Water and Surface-Water Interaction

In a surface-water monitoring study, ground-water discharge and recharge must be evaluated so that ground-water/surface-water interactions can be characterized. This information is necessary to accurately assess contaminant migration on and off RMA. From the current understanding of ground-water and surface-water relationships, four areas have been identified for monitoring: First Creek, the area around the lakes near South Plants, Havana Pond, and the Uvalda Interceptor.

3.4.1 Scope of Investigation

The prominent streams and lakes are located in the Irondale Gulch Drainage Basin and First Creek Drainage Basins (Plate 2.3-1) and were monitored to evaluate ground-water and surface-water interaction. The following four areas are critical to the understanding of ground-water and surface-water interaction.

3.4.1.1 First Creek. First Creek crosses RMA from the southeast (Section 8) and leaves the RMA in Section 24 (Figure 1.1-2). On occasion First Creek receives surface runoff from Upper Derby outflow and North Plants when water levels are high. It may also at times be receiving treated effluent from the sewage treatment plant located in Section 24. Its drainage area overlies many contaminated aquifer units. First Creek is the primary route for surface water leaving RMA. Previous studies have suggested that both recharge and discharge of ground water occur in the First Creek drainage (RCI, 1982); therefore, this is a possible path of migration of contaminants off RMA.

3.4.1.2 South Plants Lakes. The lakes area, which is in the southern region of RMA, just south of South Plants (Figure 1.1-2), includes Eastern Upper Derby Lake, Upper Derby Lake, Lower Derby Lake, Ladora Lake, and Lake Mary. Water flows in a southerly direction from South Plants to Upper and Lower Derby Lakes. From Eastern Upper Derby Lake to Lake Mary, water flows from east to west. Water also flows from the south from Uvalda Interceptor to either Lower or Upper Derby Lakes. Surface-water in the lakes is also derived from Havana Pond and the Sand Creek Lateral. This water is usually placed in Ladora Lake. Much of the RMA contamination was derived from South Plants; thus it is important to assess the ground-water/surface-water interaction and monitor any contamination in the area.

3.4.1.3 Havana Pond. Havana Pond is located in Section 11 near the southwest entrance of RMA. Surface water flows into Havana Pond from Havana Interceptor and Peoria Interceptor (Figure 1.1-2). Mass balance calculations and water-level data (Ebasco Services, Inc., et al., 1989a)

strongly suggest that all of the water in the pond becomes ground-water recharge. At high flood stages, water flows from Havana Pond to the lakes area via Sand Creek Lateral, so it is important to monitor the surface-water flow in this area.

3.4.1.4 Uvalda Interceptor. Storm drainage from the Montbello residential area enters RMA from the Uvalda Interceptor (Figure 1.1-2). A consistent base flow is observed at the South Uvalda gaging station suggesting that ground water is discharging to the interceptor. The year round baseflow that has been observed at the station is unrelated to any surface runoff that may originate from the Montbello residential area.

3.4.2 Strategy and Methods

In order to characterize the ground-water/surface-water interaction on RMA, water levels, ion and organic data of surface water sampling sites and ground-water wells were compared. Weekly lake and pond water levels were measured using staff gages, and a Stevens Type F recorder continuously recorded levels at Havana Pond. Water level data for the wells were collected in October, February, March, April, June, and September. Ion data were compiled from spring 1989 surface-water and ground-water sampling efforts. Organic data were obtained from the spring surface-water sampling and the spring FY89 CMP ground-water sampling. A gain-loss study was also conducted which included discharge measurements taken along the southern reaches of First Creek and Uvalda Interceptor.

The ground-water wells used to help delineate ground-water/surface-water interaction were chosen on the basis of proximity to surface-water monitoring and sampling stations and are listed in Table 3.4-1. Plate 3.4-1 shows the wells chosen for this study in FY89.

Table 3.4-1 Wells Used to Delineate Ground-Water/Surface-Water Interaction

Hydrograph Data

01001, 01024, 01028 (D), 01049, 01069, 01070, 01073, 01074, 01075, 01076 (D), 02001, 02008, 02026, 02034, 02050, 02052, 02055, 02056, 02059, 02060 (D), 11002, 11007

Water Level Data

01021, 01027, 01044, 01047 (D), 02010 (D), 02020, 02022 (D), 07001, 08002, 08003, 11008, 12001, 12002, 24110, 24188, 25011, 30001, 30011 (D), 31005, 31016, 37343

Ion and Organic Data

01047, 01073, 01074, 02034, 02055, 02056, 02059, 02060 (D), 24188, 31016, 37343

(D) - Well completed in the Denver Formation.

3.4.2.1 Comparison of Hydrographic Data. Water level measurements in 43 wells were used to assess ground-water/surface-water interaction. In comparison to FY88, additional wells in the South Plants Lakes area were included in the FY89 water level network. Ground water levels in several cluster wells, completed in alluvial and Denver zones, were measured in order to further characterize ground-water/surface-water interaction. Wells completed in the Denver Formation are indicated on Table 3.4-1.

Available water-level data and sampling data from these wells were compared to data from adjacent surface-water monitoring stations. Hydrograph data for the South Plants Lakes and Havana Pond and corresponding adjacent wells were used to analyze communication between surface water and ground water. Additional water-level data, if applicable, were used to delineate areas of discharge and recharge. These wells are identified in Table 3.4-1.

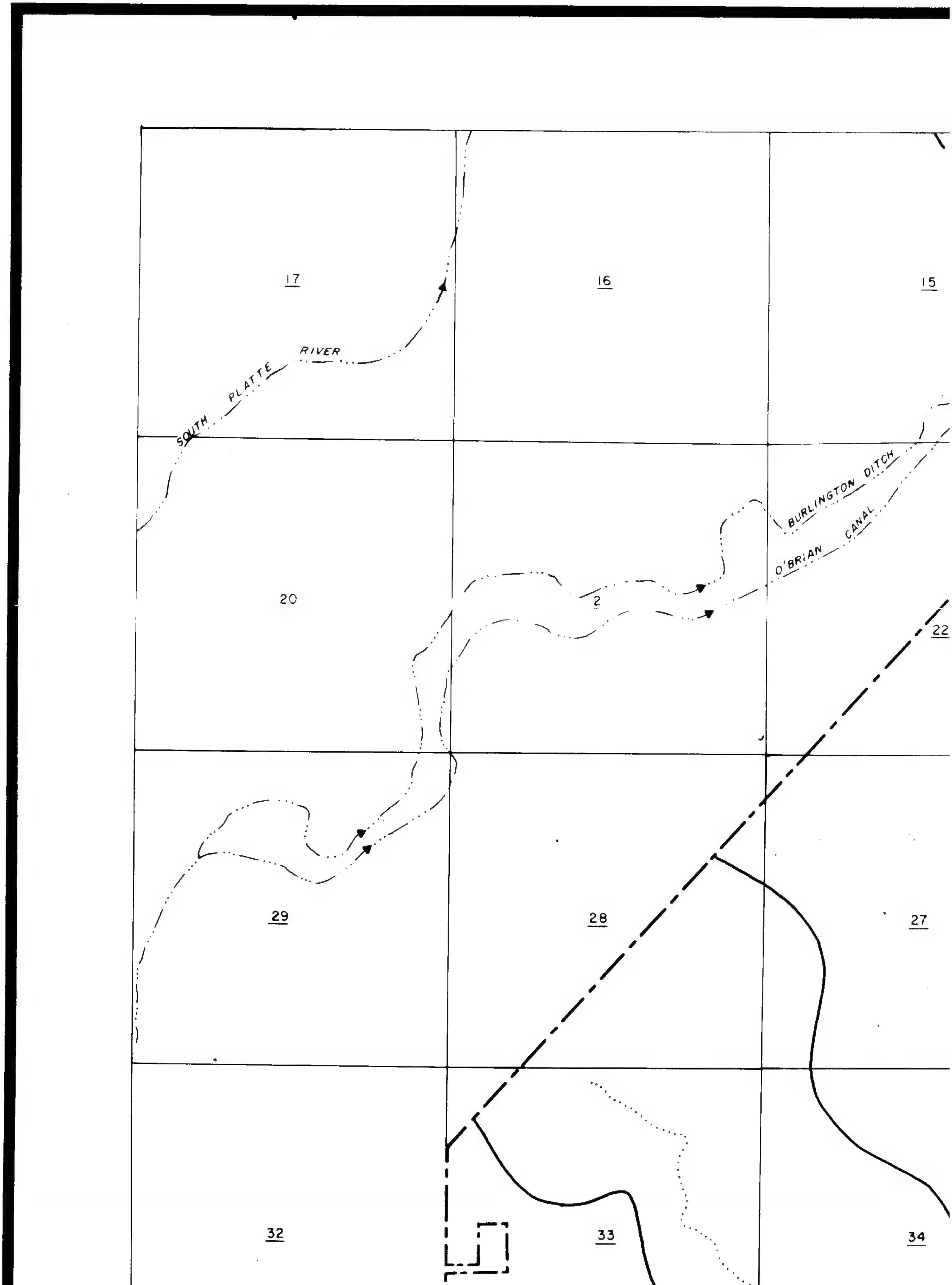
3.4.2.2 Comparison of Ion and Organic Data. Ion data and organic data were used to find areas in which ground water and surface water had similar compositions. Analytical results from wells were compared to analytical results from surface water stations in the First Creek and South Plants Lakes areas. The wells are listed in Table 3.4-1. Ground-water/surface-water interaction may be indicated by similar ground-water and surface-water compositions.

In order to compare surface-water and ground-water ion data, the data was first determined to be complete and acceptable. Ion balance calculations were not performed for the fall or storm samples because concentrations of two of the anions, carbonate ($CO_3^{=}$) and bicarbonate (HCO_3^-) could not be calculated from the titration endpoints reached in the laboratory. Carbonate and bicarbonate concentrations are calculated from measurements of the phenolphthalein and total alkalinities. For waters with pH less than 8.3, the total alkalinity is the bicarbonate alkalinity (as $CaCO_3$) and there is no phenolphthalein alkalinity. Waters with a pH greater than 8.3 have a phenolphthalein alkalinity and a total alkalinity. The concentrations of each carbonate species are dependent on the magnitude of the two alkalinities.

In the spring, field alkalinity measurements were taken in 26 surface-water samples and in 11 ground-water samples. In four of the surface-water samples, the phenolphthalein alkalinity was not measured and bicarbonate concentrations could not be calculated. An ion balance calculation was performed on data from the remaining 22 surface-water samples and 11 ground-water samples. In general, when anion and cation data balanced to within ±5 percent of 100 percent, the data are considered to be acceptable. A majority of the samples met this criteria and, for those that did not,

the results were determined to be generally consistent with concentrations in samples from adjacent locations. The ion concentrations in samples from the wells were compared to ion concentrations in surface-water samples using Stiff diagrams, in order to analyze ground-water/surface-water interaction.

3.4.2.3 Gain-Loss Study. A gain-loss study was conducted on First Creek and on Uvalda Interceptor to help determine the degree of ground-water/surface-water interaction in these areas. Discharge measurements were taken at three points on each of the channels and were used to determine if the streams were either effluent (gaining) or influent (losing). Discharge measurement sites SW08001, SW08003 and SW08004 were chosen on First Creek, and sites SW12005, SW12008 and SW12009 were selected on Uvalda Interceptor (Plate 3.4-1). All of the discharge measurements were taken using a 200 mm long-throated flume on September 29, 1989.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BURLINGTON DITCH
O'BRIAN CANAL
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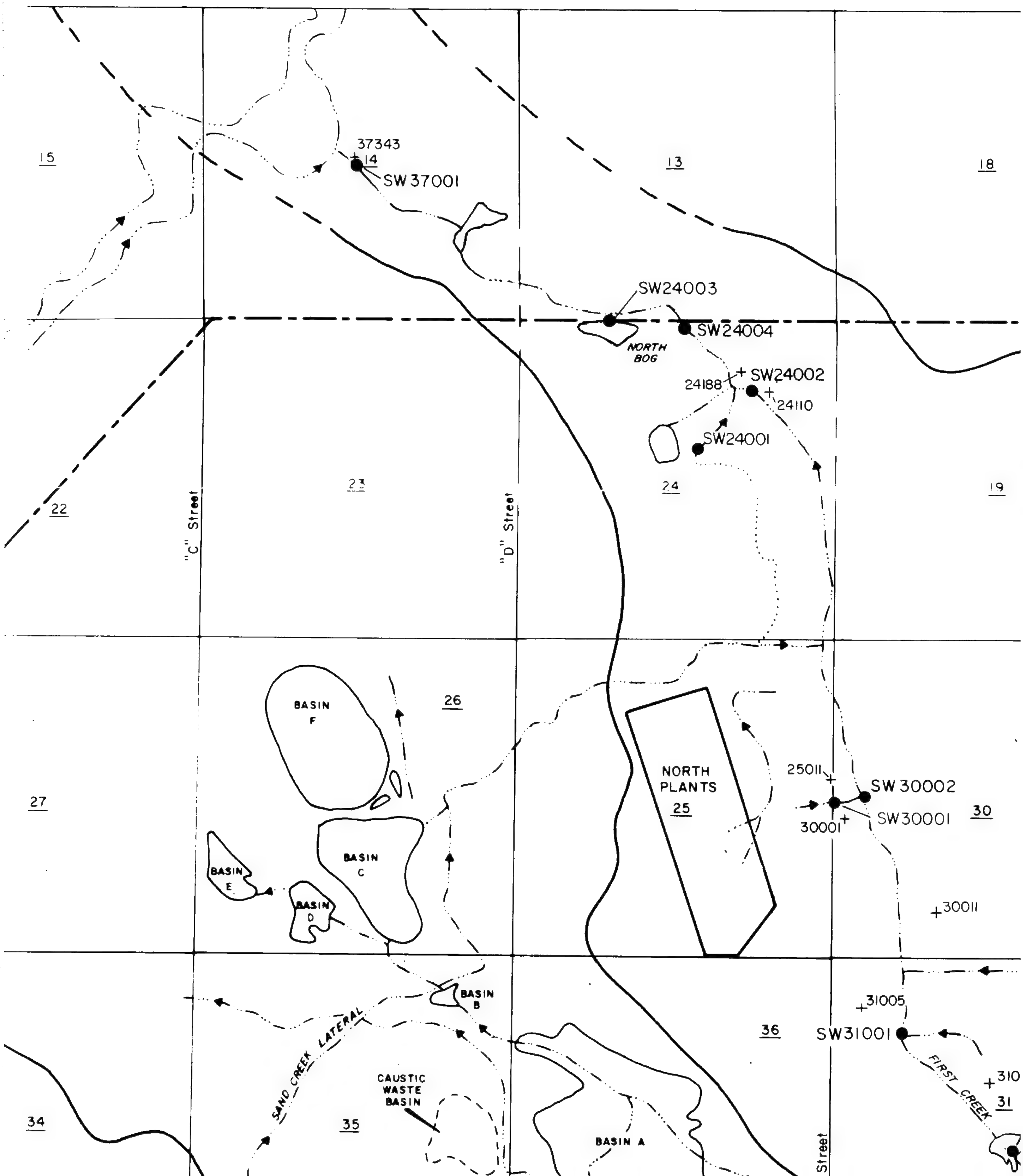
3



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37343
14
SW37001
13
18
SW24003
SW24004
NORTH BOG
24188
SW24002
24110
SW24001
22
"C" Street
23
"D" Street
24
19
BASIN F
26
27
NORTH PLANTS
25
25011
SW30002
SW30001
30001
30
BASIN E
BASIN C
BASIN D
30011
BASIN B
31005
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SW31001
SAND CREEK LATERAL
CAUSTIC WASTE BASIN
FIRST CREEK
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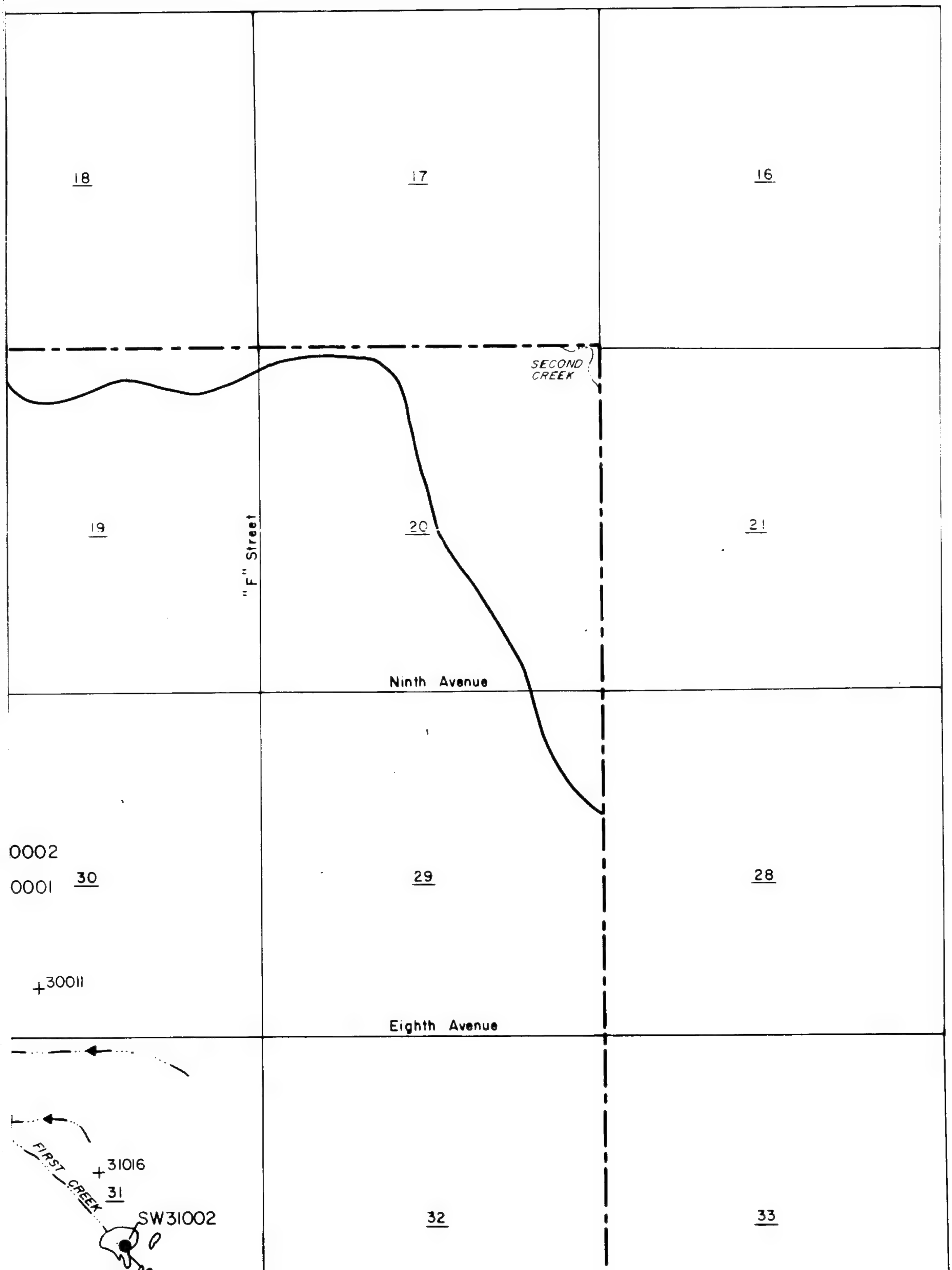
31
34
35
BASIN A
Street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19
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32
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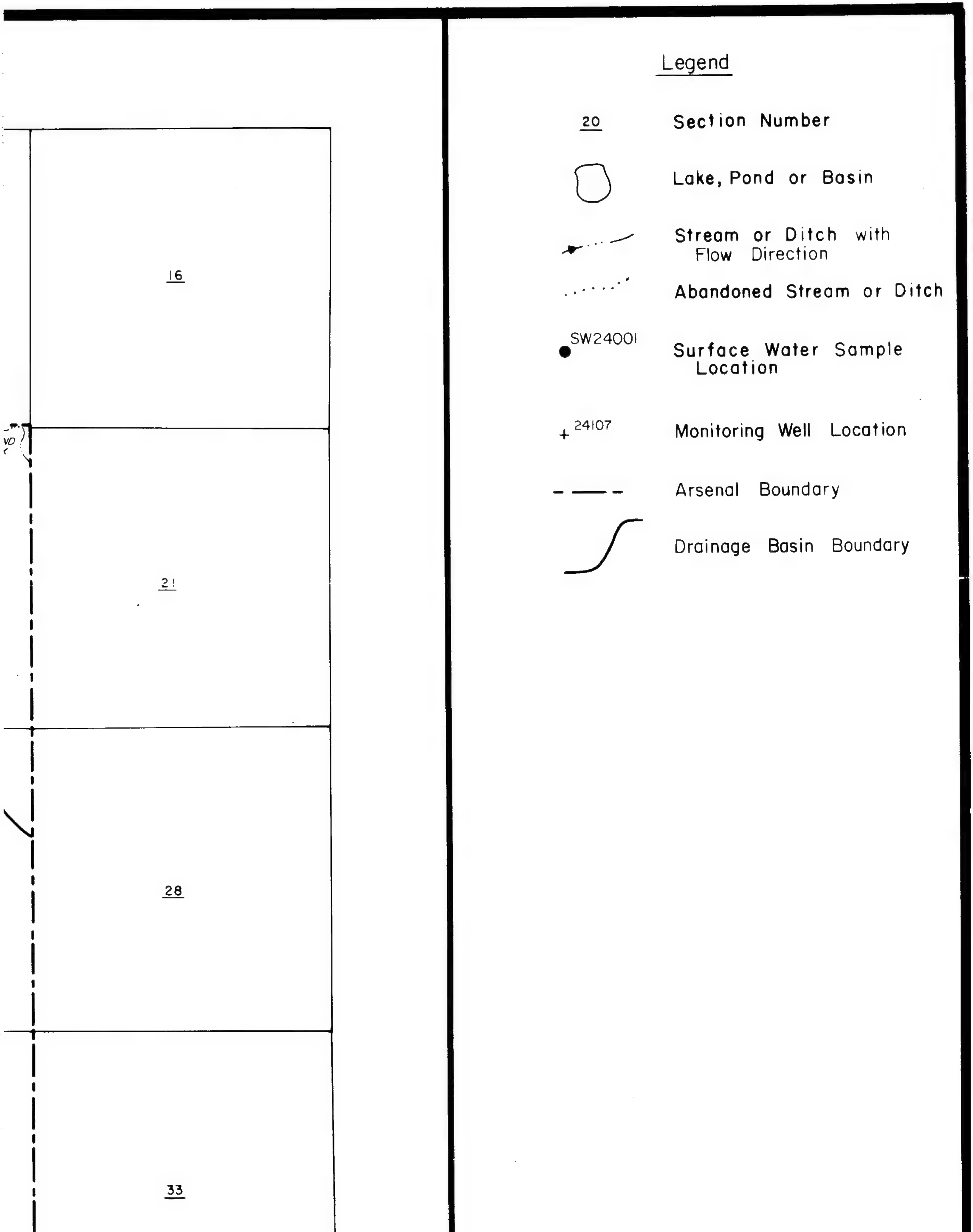
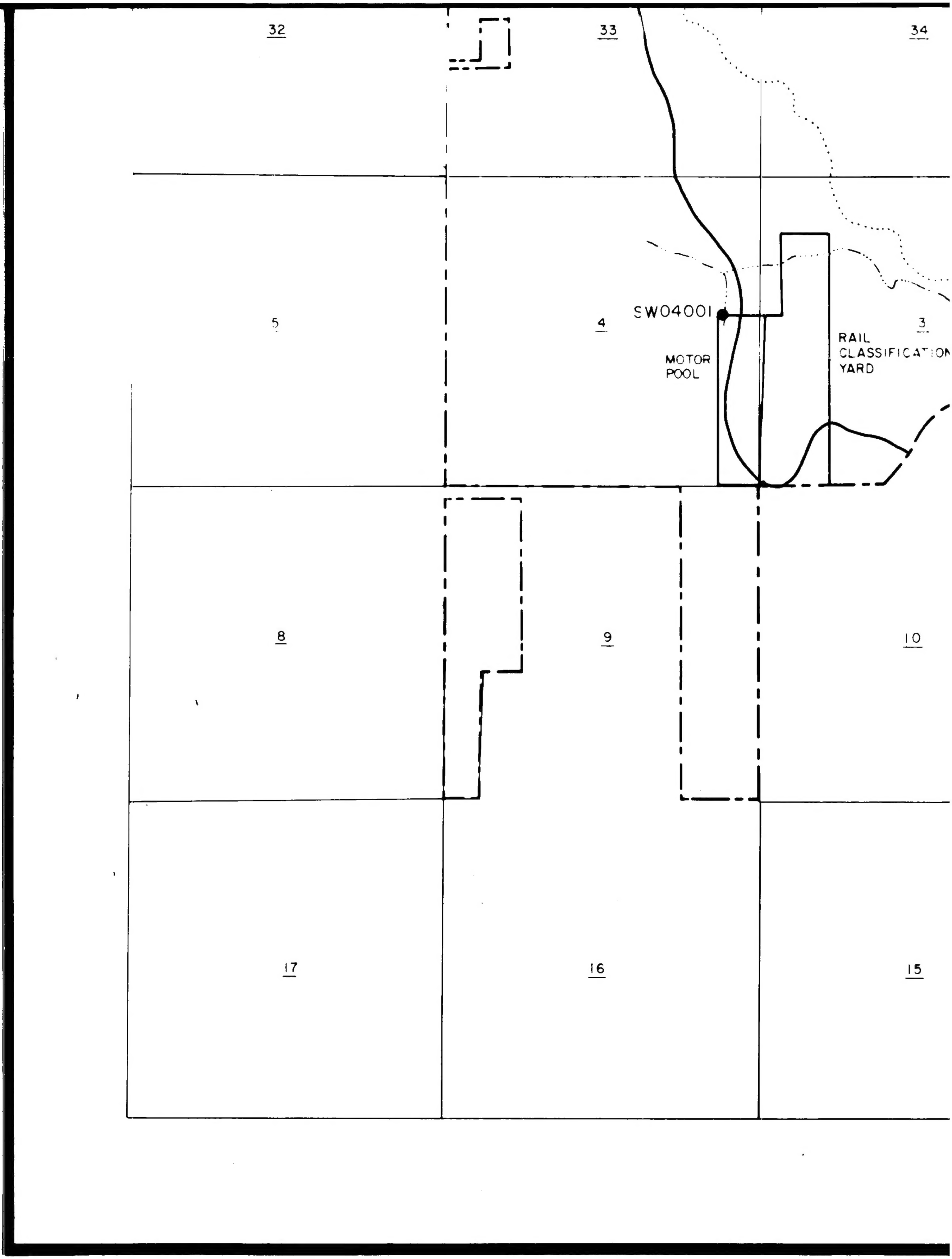

16
21
28
33
Legend
20 Section Number
Lake, Pond or Basin
Stream or Ditch with Flow Direction
Abandoned Stream or Ditch
SW24001 Surface Water Sample Location
24107 Monitoring Well Location
Arsenal Boundary
Drainage Basin Boundary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33
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4
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SW04001
MOTOR
POOL
RAIL
CLASSIFICATION
YARD
8
9
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16
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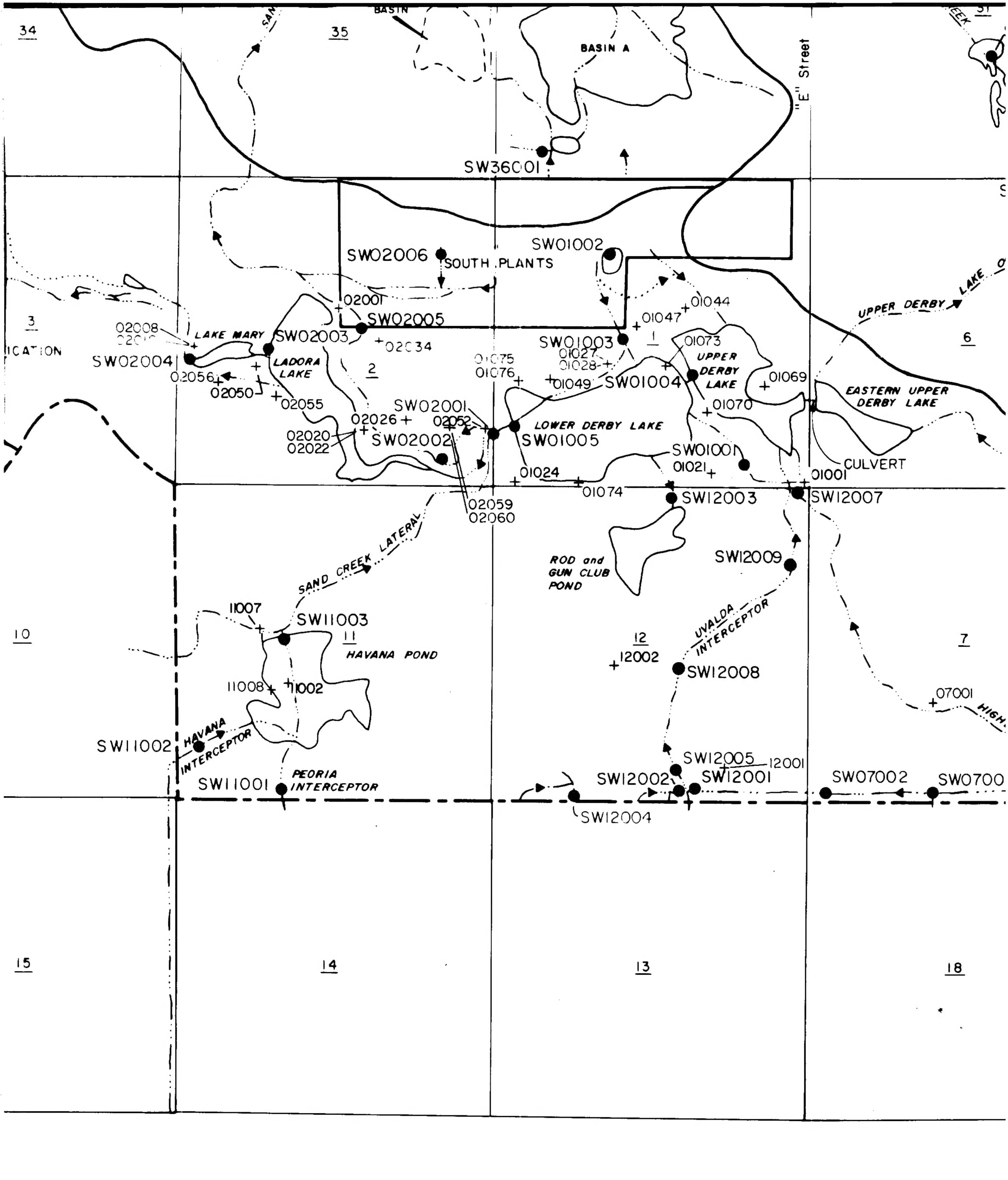

34
35
BASIN
BASIN A
"E" Street
SW36001
SW02006
SOUTH PLANTS
SW01002
02001
SW02005
01044
01047
UPPER DERBY LAKE
3
02008
LAKE MARY
SW02003
02034
SW01003
1
01073
6
ICATION
SW02004
LADORA LAKE
2
01075
01076
01027
01028
UPPER DERBY LAKE
01069
EASTERN UPPER DERBY LAKE
02056
02050
02055
01049
SW01004
01070
SW02001
02026
02052
LOWER DERBY LAKE
02020
02022
SW02002
SW01005
SW01001
01021
CULVERT
01024
01074
01001
SW12003
SW12007
02059
02060
SAND CREEK LATERAL
ROD and GUN CLUB POND
SW12009
11007
SW11003
UVALDA INTERCEPTOR
10
11
HAVANA POND
12
7
12002
SW12008
11008
11002
07001
HIGH
SW11002
HAVANA INTERCEPTOR
SW12005
12001
PEORIA INTERCEPTOR
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SW12002
SW12001
SW07002
SW0700
SW12004
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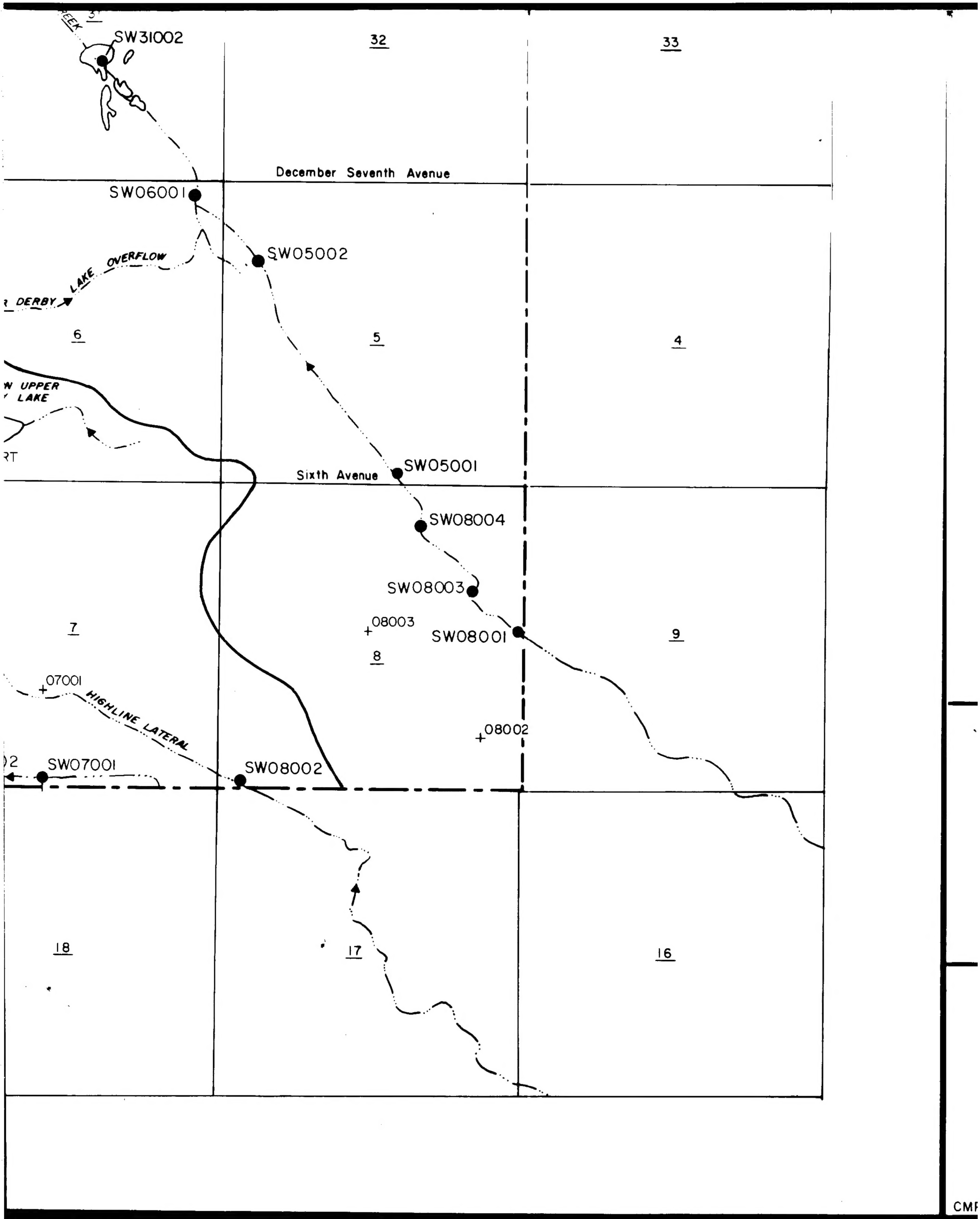
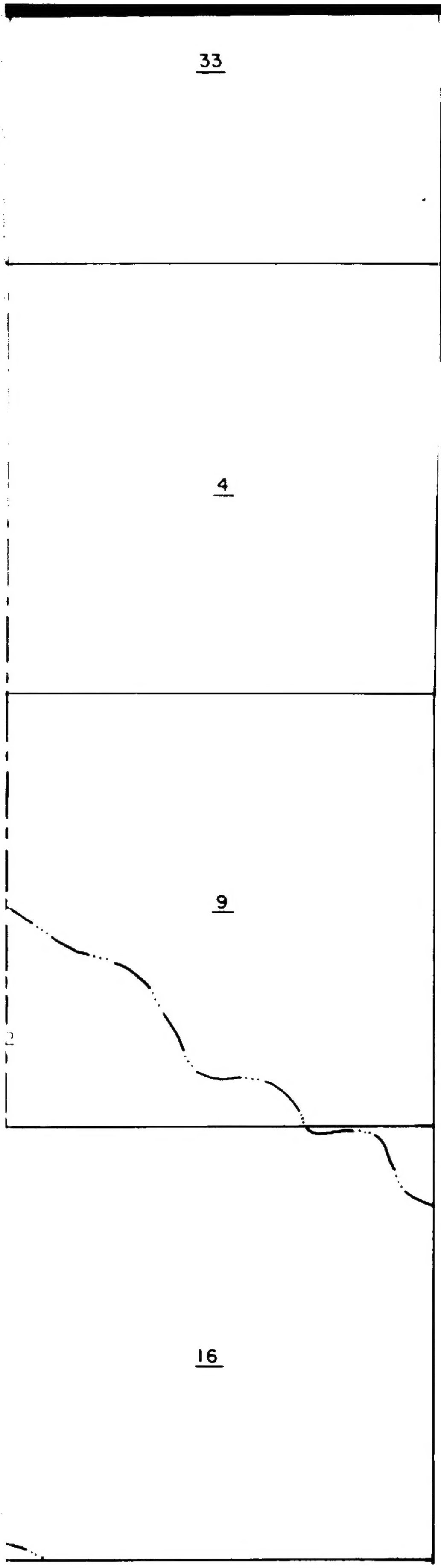
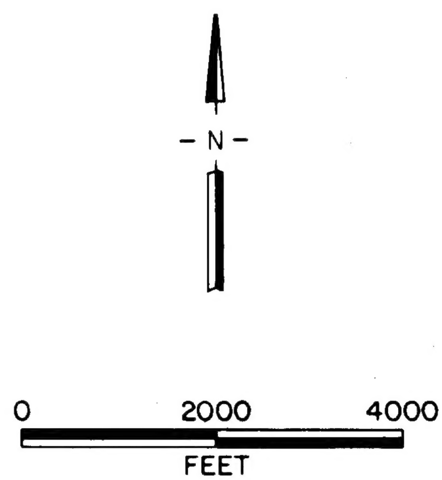


SW31002
32
33
December Seventh Avenue
SW06001
SW05002
LAKE OVERFLOW
DERBY
6
5
4
UPPER
LAKE
RT
Sixth Avenue
SW05001
SW08004
SW08003
08003
SW08001
7
8
9
07001
HIGHLINE LATERAL
08002
SW07001
SW08002
18
17
16
CMF





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Harding Lawson Associates

Plate 3.4-1

Location Map of Surface-Water Sampling Sites and Monitoring Wells used for Ground-Water/Surface-Water Interaction Study

CMP SW FY 89